USGS

Natural Science and Public Health: Prescription for a Better Environment

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Conference Abstracts

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Many U.S. Geological Survey scientists have conducted pioneering research on the relationship between the natural environment and human health. Much of the work presented at this conference has benefited from the efforts of these trailblazers.

Foreword: *Natural Science and Public Health*

Health problems caused by natural occurrence of causative elements, environmental contamination and emerging infectious diseases are a growing concern worldwide. Ground-water contamination, trace-metal poisoning, waterborne microbial infections --- these and other environmental threats to public health require innovative, science-based solutions.

Over the past 124 years, USGS science has provided vital information for understanding and solving many scientific and environmental problems facing this country. Our core capabilities in water quality, environmental geochemistry, wildlife disease, geospatial technology and many other fields enable USGS to be a significant partner in the area of natural science and public health as we work together to write a "***Prescription for a Better Environment***."

USGS involvement in human health occurs through strong partnerships with health and environmental organizations. Partnerships between the USGS and these organizations can pinpoint environmental causes, lead to effective solutions, and save lives. USGS science researchers are working closely with the public health and biomedical research community to pursue rigorous inquiries into the connections between natural science and public health.

With geographic distance and isolation no longer meaningful barriers, the opportunities for once isolated diseases to spread have never been greater, as demonstrated by the rapid spread of a deadly pneumonia-like illness that originated in southern China in November. Our children and grandchildren will face many public health challenges, which will continue to emerge and evolve, posing new risks for the foreseeable future.

Data from the Centers for Disease Control and Prevention indicate that nearly a million cases of illness each year occur in the United States because of waterborne microbial infections. Incidence of asthma and other respiratory disease, certain cancers, and emerging new diseases are increasing. A wide variety of wildlife species have been identified as hosts or reservoirs for emerging infectious diseases that threaten both human and domestic animal health. According to the National Institute for Environmental Health Science, more than 80,000 chemicals are used in the United States and an estimated 2,000 new ones are introduced annually. The impacts of these on health are not clear. USGS studies have documented atmospheric dust that carried heavy metals, pesticides, and pathogens such as soil fungus from Africa to the United States. The harmful effects of toxicants such as lead, mercury, radionuclides, and arsenic on humans and animals are well known, but scientists do not yet fully understand their distribution and circulation in the environment. Increasing waste effluent has been related to outbreaks of *E. coli* and cholera, while *Pfiesteria* and other harmful algal blooms can affect people, fish, and wildlife.

USGS is focusing on new applications of our core capabilities, building collaborative relationships with partners to address significant health issues facing the United States today, bringing our expertise to bear on resolving these problems, and increasing our knowledge to provide more effective tools and information. We have the ability to bring together large, diverse datasets, conduct complex geospatial and statistical analyses, create interactive decision support models, and interpret data to produce unique and specialized derivative map products.

As noted by the National Research Council in their report *Future Roles and Opportunities for the USGS*, "the intersection between natural sciences and the allied health sciences remains an under-explored field." We see ourselves as explorers.

This conference is just the beginning. The research highlights presented here are important not only because of their scientific contributions but also because they show the powerful possibilities for the integration of natural science and health science in solving these complex societal problems.

Charles G. Groat
Director, U.S. Geological Survey
April 2003

Pliocene Coal, Water Quality, and the Etiology of Balkan Endemic Nephropathy

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Balkan endemic nephropathy (BEN) is a tubulointerstitial kidney disease restricted to individuals living in clusters of rural villages in Bosnia, Bulgaria, Croatia, Romania, and Yugoslavia. The disease has a long incubation period, striking most individuals at 50-70 years of age, and requiring at least 20 years residence in a BEN village. Many of the characteristic features of BEN suggest a possible environmental etiology [1], but no definitive cause(s) has been proven. A team of USGS geoscientists and medical researchers from BEN-affected countries are currently examining a possible environmental etiology for BEN.

Work by the USGS in the early 1990's [2] showed a close geographic correspondence between BEN villages and coal deposits (Pliocene lignites). Other studies [3,4] showed that well water from BEN villages appeared to have higher concentrations of dissolved organic substances compared to well water from control (i.e. non-BEN) villages. This led to the development of a hypothesis, which postulates that the etiology of BEN is linked to long-term consumption of well water containing toxic organic compounds leached from Pliocene lignites by groundwater (Pliocene lignite hypothesis). Villages affected by BEN use shallow wells as a primary water source. Recent studies by our interdisciplinary team aimed at validating this hypothesis [5,6,7,8] have shown that: (a) Pliocene lignites from BEN areas readily leach many types of potentially toxic organic compounds into aqueous solution, (b) well water samples from BEN villages contain a greater abundance of potentially toxic organic compounds as compared to controls, and (c) epidemiological studies show that BEN villages that have switched from well water to treated water have experienced a dramatic drop in the incidence of BEN. These results support our working hypothesis on the environmental etiology of BEN. Ongoing studies are aimed at further geochemical validation and on toxicological experiments.

USGS Studies Related to Metal-rich Coal in Southwestern Guizhou Province, China

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We are engaged in a collaborative program with Chinese and United States earth-science and medical researchers to address the occurrence of conditions such as arsenic poisoning and dental and skeletal fluorosis, related to domestic combustion of mineralized coal in southwestern Guizhou Province, China. The link between these diseases and domestic combustion of coal has been established by environmental and epidemiological research. Arsenic and fluorine are the principal causes of the health problems attributed to domestic coal combustion, although there may be some evidence of mercury and thallium poisoning. The use of locally mined, high-arsenic (>100 ppm) coals has caused arsenic poisoning in several villages. The primary pathway appears to be through ingestion of foods, especially chili peppers, dried over open coal stoves. Air pollution-type fluorosis appears unrelated to fluorosis due to consumption of fluorine-rich groundwater. The air pollution-type of fluorosis affects millions more people than arsenic poisoning. The primary path of human introduction of fluorine is also related to drying food, especially corn, over unvented coal stoves. In this case, preliminary studies indicate that corn preferentially adsorbs fluorine from fluorine-rich coal smoke.

Chinese Public health officials have recognized the etiology of these diseases and have established programs to restrict the use of metal- and fluorine-rich coal for domestic combustion. The geologic and geochemical challenge will be the identification of acceptable local alternative sources for coals low in arsenic and fluorine.

Effects of Enhanced Zinc in Drinking Water on Brain and Memory

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Zinc is one of the most soluble of the transition metals in natural waters: The adverse effects of zinc deficiency have been studied extensively, but the problem of abnormally high levels of zinc has received less attention. Because zinc must be transported through the blood-brain barrier, it has been thought unlikely that environmental factors could change brain levels. In contrast, we have shown that long-term exposure to zinc in drinking water can change both spatial memory and brain levels of zinc in rats, but that this depends on the anion with which the zinc is initially associated.

We have examined whether drinking water with 10 ppm zinc as carbonate, $ZnCO_3$, or sulfate, $ZnSO_4$, (the most common anion associations in natural waters) would affect both brain levels of zinc and spatial memory in Sprague-Dawley rats. Synchrotron X-ray fluorescence (SXRF) was used to measure metal distributions in 20-micron slices. This technique allows tissue analyses to be done with no chemical pretreatment, with low detection limits (about 1 ppm), and provides non-destructive measurements at spatial resolutions of 10um or less. Zinc concentrations in rat hippocampus and cortex increased following long-term ingestion of the $ZnCO_3$-enhanced drinking water associated with deficits in spatial memory (investigated using the Morris Water Maze). No increase was seen following ingestion of $ZnSO_4$-enhanced water, which did not lead to impairment in spatial memory. Copper concentrations were comparatively lower in rats exposed to $ZnCO_3$ than in controls.

Preliminary results show that, compared to surrounding tissue, elevated levels of K, Zn, Cu, and Fe are found in amyloid plaques associated with Alzheimer's disease. The concentrations vary across the plaques and are different in diffuse plaques, which predominate early in the disease, and dense-core plaques, which predominate in later stages.

Working toward a Better Understanding of Health Hazards Caused by Volcanic Air Pollution on the Island of Hawai‘i

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Beginning in mid-1986, when the current eruption became continuous, air pollution from Kilauea volcano, known locally as vog, became an unfortunate part of everyday life for Hawai‘i residents and visitors. Since then, the volcano has released about 1,600 tonnes of irritating sulfur dioxide (SO_2) per day, roughly 6,000 times the emissions that the EPA defines as a major industrial source. The emissions are converted by oxygen, moisture and sunlight to a gas and aerosol mixture rich in sub-micron acidic particles capable of being drawn and retained deep in the lung.

The acidic nature of vog causes unquantified respiratory effects, rapidly corrodes metal objects, damages crops, degrades domestic water quality and has been linked to locally decreased rainfall. Depending upon wind direction, some portion of the island of Hawai‘i and its 150,000 residents is chronically affected. During trade wind disruptions, all eight principal islands, stretching 350 km to the northwest, can be impacted as well.

When trade winds are disrupted, vog buildup in east Hawai‘i degrades air quality for residents and some of Hawai‘i Volcanoes National Park’s 2.3 million annual visitors. The emissions have taken at least one life directly, and from 1986 to 1993, during a period of continuous eruption, asthma deaths island-wide exceeded those expected by 300 percent.

USGS scientists, health care professionals, university researchers, educators, and the community are working together to understand vog’s health effects through an initiative funded by the National Institute of Environmental Health Sciences (NIEHS). The 5-year study will examine vog exposure, symptoms, and lung development in school children on the Island of Hawai‘i. While this work proceeds, the USGS, in collaboration with the National Park Service, has developed a real-time system to inform and advise park visitors and employees when vog levels, as approximated by ambient SO_2 concentration, exceed prescribed amounts.

Rift Valley Fever: The Interplay of Climate, Landscape Ecology and Epidemiology

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Rift Valley fever (RVF) is an important emerging epidemic disease of humans and domestic animals in sub-Saharan Africa. Massive epizootics are typically observed in domestic livestock during times of sustained high rainfall. Humans and other species are also infected in inter-epidemic periods. At present, however, there is no way to predict RVF epidemic/epizootic activity in specific locales.

RVF virus (RVFV) is transovarially transmitted within infected *Aedes* mosquitoes breeding in seasonally flooded depressions called dambos. Infected eggs may persist in dry sites for several years. Epidemics can arise when very high rains result in water accumulation in dambo oviposition sites. Though explosive outbreaks are associated with heavy rains, there are no controlled observations published that allow one to use rainfall to anticipate virus circulation. Moreover, relying on rainfall monitoring to predict RVF epidemics ignores multiple climate and ecological factors. With the hypothesis that we can predict sub-regional-scale RVFV activity prospectively using a combination of ecological, climate, and remote sensing variables, the primary scientific goal of the proposed project is to develop and validate predictive algorithms and models for RVFV activity and epidemics based on these variables.

The study will focus on the High Plateau ecological zone in Zimbabwe, where a database of RVF activity exists, with gaps, from the mid-1950s to the early 1990s. Remote sensing (RS) data will be utilized to characterize the climate, ecology and topography of study sites. A 30-year site record of RVFV isolations will be compared with archived RS data. Data will be analyzed for correlations using various statistical approaches in order to quantify the variables that most affect RVFV transmission.

Spatial Forecasting of Disease Risk and Uncertainty

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Because maps usually represent the value of a single variable over 2-dimensional space, they must simplify such problems as multiscale complexity, temporal dynamics, and underlying uncertainty. A choropleth disease risk map based on data for polygonal regions might depict incidence (cases per 100,000 people) within each region for a year but ignore the uncertainty that results from finer-scale variation, generalization, misreporting, small numbers, future unknowns, etc. The problem of Lyme disease forecasting for each of the United States is used to illustrate an approach to bivariate mapping of data "quantity" and data "quality." Historical state data 1990-2000 are used in an autoregressive model to forecast both 2001-2010 disease incidence as well as a probability index of uncertainty, each of which is then kriged to provide two spatial grids. A bivariate map is produced from the combination of incidence (mapped on a blue-red hue spectrum), and probability (used to control the saturation of the hue at each grid cell). The resultant maps are easily interpretable, and the approach may be applied to such problems as detecting unusual disease occurrences, animating past and future incidence, and assembling a consistent regional disease atlas showing patterns of forecasted risks in light of uncertainty.

Community Level Analysis of Vector Borne Disease

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Ecological community structure in communicable disease can be a key factor in understanding the risk to public health of disease emergence, the mode of transmission, and the control options (Forget and Lebel, 2001). This consideration would seem particularly important in vector-borne zoonotic diseases with complex life cycles. Population models, such as the Ross-Macdonald model (Bailey, 1982), have been important in developing and characterizing our current understanding of human vector-borne disease. However, these models often by-pass or minimize community-level interactions. In diseases restricted to human hosts, this focus may be of benefit in understanding transmission, but in zoonotic diseases in particular, important community-level considerations may be lost (LoGuidice et al., 2003). Another limitation is that the level of quantification possible in population models may not be achievable in community models.

Qualitative community model analysis (Puccia and Levins, 1991) may provide a meaningful alternative to modeling vector-borne disease. We build on recent mathematical developments in qualitative community modeling (Dambacher et al., 2002) coupled with conventional biomathematical models of vector-borne disease transmission, to provide new procedures to analyze risk. Our procedure predicts the change in risk of vector-borne disease from press perturbations, such as control measures, anthropogenic habitat alteration or global warming. We demonstrate the application of this procedure to an oak forest community to predict the risk of Lyme disease.

Discovery and Interactive Development of Community Level Models of Disease Transmission: West Nile Virus in Maryland

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Understanding interactions among pathogens, hosts, and the environment is important in developing rapid responses to disease outbreaks. Traditionally, epidemiologists employ highly structured and comprehensive methods to gather quantitative information to establish cause-and-effect relationships between environmental stressor(s) and disease. This approach is time consuming and resource-intensive, particularly during a disease outbreak. To complement this approach, we demonstrate the use of Relational Bayesian Models (RBMs), models discovered in relational data using machine learning technology, to rapidly construct quantitative and biologically-consistent models of West Nile virus (WNV) spread using existing, observational data.

Discovered models integrate survey data concerning WNV cases in mosquitoes, horses, humans, and birds in Maryland collected during 2001, along with information about tire clean-up sites and collection facilities. The RBMs produced in the analysis are complete representations of the joint probability distribution over the entire set of variables included in the model and may be used as a tool to frame multiple, simultaneous hypotheses concerning these variables. We constructed a common frame of reference to temporally and spatially relate data collected in independent survey efforts that reside in independent data tables. Using this frame of reference, CleverSet Modeler, the tool used, heuristically examined all possible models that could be derived using the available variables to discover those models that parsimoniously describe the probabilistic relationships among the variables in the model. These relationships form the basis for hypotheses about the key factors involved in transmission of the disease and the manner in which the disease spreads. Our results indicate a strong association between tire license sites and birds infected with WNV, and that positive birds serve as good indicators for infected mosquitoes and humans.

RBMs show promise as a tool to explore complex community interactions relevant to disease transmission. RBMs can be used to identify probabilistically, those variables that may be important during an outbreak, even from sparse survey data that precludes the use of other modeling approaches. The information derived from the RBM may be used to assist in formulation of rapid response, to guide monitoring and control strategies and to assess spatial and temporal links in the epidemiological evaluation of disease transmission during the early stages of an outbreak or during an ongoing outbreak of a relatively rare disease.

Vaccination as a Potential Means for Controlling Sylvatic Plague

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Sylvatic plague, caused by the bacterium, *Yersinia pestis*, is primarily a disease of wild rodents that afflicts humans as well as other animals. Unfortunately, current methods to control the disease are unsatisfactory and native rodents, such as prairie dogs and ground squirrels, have become an important reservoir of the disease for humans in North America. Experiments are being conducted to evaluate vaccination as a means for controlling plague in wild animals using a recombinant vaccine. This vaccine utilizes raccoon pox virus (RCN) as a vector for the capsular antigen of *Y. pestis* (F1). A major advantage of using an RCN-vectored vaccine over a traditional protein vaccine, such as the F1 protein, is that it can be delivered orally, a critical requirement for immunization of free-ranging wildlife. Black-tailed prairie dogs, *Cynomys ludovicianus*, were offered sweet potato/gelatin baits that contained the vaccine (RCN-F1) for voluntary consumption. Three weeks after the initial immunization, the animals were boosted similarly by voluntary consumption of additional vaccine-laden baits. Controls received sham baits with no vaccine. Blood was drawn from all animals prior to immunization and at periodic intervals thereafter; anti-F1antibody titers were measured using an enzyme-linked immunosorbent assay (ELISA). Three weeks after the second immunization, all animals were challenged with virulent *Y. pestis* at a dose that might be encountered in nature. Anti-F1 antibody titers were significantly elevated in immunized animals compared to pre-vaccination values and controls. Also, survival to challenge was significantly enhanced in immunized animals compared to controls. These results demonstrate that prairie dogs can be immunized against plague by ingestion of vaccine-laden baits. Further work is in progress to improve the vaccine and to devise effective bait formulations that are palatable to wild rodents and easy to distribute.

Environmental Predictors for Tick-borne Disease Risk in the Middle Atlantic Region, USA

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Lyme disease is the most common vector-borne disease in the USA. The Middle Atlantic region is a major focus of this disease, and of human granulocytic ehrlichiosis -- an emerging and deadly disease transmitted by the same ticks that spread Lyme disease. Based on extensive field sampling in 1997 and 1998, a spatial statistical model was used to successfully predict sites with environmental factors conducive to supporting tick populations -- the primary risk factor for human Lyme disease. This model, incorporating spatial autocorrelation and adjusting for overdispersed distributions, revealed that distance to deciduous forests and water bodies, as well as elevation, land cover and soil type, were significantly correlated with Lyme disease risk.

Because the link between soil and risk found in this previous work was relatively nonintuitive and difficult to interpret, we examined this further. When a more informative and finer resolution soil database became available for a subset of our field sites, we reanalyzed that subset and confirmed that significant associations between soil features (such as texture and water-holding capacity) and tick abundance remain robust. The combination of analyses generated the hypothesis that climatological and physical factors interact to affect tick habitat suitability, and hence are strong determinants for human Lyme disease risk. For the present study, climate data and human case data were obtained for the years corresponding to our field-collected tick data, and initial results suggest that precipitation, but not temperature, is correlated to human Lyme disease case reports. Current investigations are quantifying the extent to which climate and soil factors interact to affect the development and success of tick populations, and thus human tick-borne disease risk. Better understanding of the environmental factors that promote tick and pathogen survival and transmission can help target more effective interventions and reduce the public health burden of tick-borne diseases.

Transmission Dynamics of Vector-borne Zoonoses: Implications for Disease Management and Natural Resource Conservation

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Zoonoses can affect natural resources both by causing disease in wild animal populations and by provoking environmentally-damaging management responses. Probabilistic models of pathogen spread through natural populations predict that fluctuations in vector numbers have a more or less linear effect on vertebrate disease incidence when pathogen prevalence in vectors is low (e.g., for most mosquito-borne arboviruses such as West Nile Virus) but not when pathogen prevalence and vector numbers are high (e.g., for Lyme disease spirochetes in endemic natural areas). Therefore, human interventions that lower vector numbers and incidence of human disease might or might not similarly affect incidence in natural populations, depending on local transmission dynamics. In addition to vector population densities, the structure of the transmission cycle (number of competent vector and reservoir species) influences growth and stability of local pathogen prevalence.

Studies of Lyme spirochete transmission at Fire Island National Seashore, NY, indicate that tick densities are locally so high that virtually all ground-dwelling mammals and most ground-foraging birds are exposed to spirochetal infection. Abundant bird and mammal species at this site vary substantially in degree of reservoir competence, so infection prevalence in nymphal ticks (the stage responsible for most human Lyme disease) depends on the distribution of larval ticks among vertebrate host species. Therefore, targeting interventions at highly-competent reservoir species can potentially interrupt the local transmission cycle. Efficient management can maximize the number of human cases prevented, while minimizing the scale of intervention, thus minimizing negative effects on natural resources. However, movement of ticks into the area on highly mobile vertebrates, including migrating birds (which are seasonally abundant at this coastal site), can potentially compromise such targeted management efforts, and substantially influence local transmission dynamics.

Out of Africa: Characterization of Microbial Communities Associated with Desert Dust and their Implications for Human and Ecosystem Health

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Each year, millions of tons of desert soil dust blow off the western African coast and ride the trade winds across the Atlantic Ocean to the Caribbean and southeastern United States. The country of Mali has been established in several studies as one of the major sources of this Saharan/Sahelian dust.

Whether microbes such as bacteria and fungi can survive the solar ultraviolet radiation received during the intercontinental trip has been questioned, however, two research groups have shown that living microbes are culturable from African dust air samples from the Caribbean. It is reasonable to assume that some of the microbial population is lost due to a variety of reasons (e.g. death, gravity) during the 5 to 7 day trip across the Atlantic. To understand the full range of microbes that may be present in the desert dust, we used microbiological and molecular techniques to identify nearly 100 bacterial and 20 fungal isolates from a series of dust storms sampled in Bamako, Mali. This 'source' population contains plant, animal, and opportunistic human pathogens from 20 different bacterial genera. The fungi are mainly *Cladosporium* sp. and *Aspergillus* sp., which contain both pathogenic and non-pathogenic members.

The transcontinental movement of microbes in African dust (as part of the global system of dust transport) has implications for ecosystem health (coral reefs), agriculture and livestock (safety of the food supply), and human health.

Use of Fish Health as an Indicator of Exposure to Contaminants in the Aquatic Environment

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Investigations in streams and rivers of the United States and in the Great Lakes have used various biomarkers to assess impacts of contaminant exposure to aquatic resources. Several useful fish biomarkers include external anomalies, internal anomalies, reproductive (endocrine) receptors and population/ community alterations. National investigations of endocrine biomarkers have described fish response of 17b estradiol, 11-ketotestosterone, vitellogenin, and stage of gonadal development associated with land and water use over broad geographic areas. Additional investigations have used indicator species to describe the relation of contaminated sediments and the prevalence of external and internal anomalies. Changes in dominant species and species diversity have also shown alterations in fish communities related to contaminant exposure.

Pathogenic Bacteria in Surface Waters: Occurrence and Association with Environmental Factors

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Surface waters are commonly monitored for the presence of fecal indicator bacteria, but little is known regarding the co-occurrence of common disease-causing (pathogenic) bacteria. Recently, the USGS Toxic Substances Hydrology Program has examined surface waters for a variety of conventional and emerging chemical contaminants including pesticides, personal care products, and human and/or veterinary pharmaceuticals. As part of this program, we are analyzing samples from 20 states for the presence of pathogenic *Escherichia coli* bacteria and evaluating relations between their occurrence and measures of land-use and water quality. Fecal coliform and *E. coli* bacteria concentrations were determined using standard methods. Enteropathogenic *E. coli* (EPEC, diarrhea in young children) and enterohemorrhagic *E. coli* (EHEC, exemplified by *E. coli* O157:H7, severe to deadly disease) were detected using a DNA-based method that differentiates three virulence genes: *eaeA* (adhesion protein, EPEC) and *stx1* and *stx2* (Shiga Toxins 1 and 2, EHEC). Positive samples were further analyzed using culture-based methods.

In preliminary analyses, EPEC were detected at most sites having concentrations of *E. coli* bacteria greater than 100 colony-forming units per 100 mL. EHEC were detected at sites where agricultural land use comprised at least 40% of the watershed. This finding is consistent with the documented animal source of these pathogens.

Relations are being examined between these pathogen detections and chemical water-quality profiles for the same samples (e.g., caffeine, triclosan, antibiotics, industrial chemicals, urban- vs agricultural pesticides, nitrogen and phosphorous, chloride, etc.). We will also analyze the same water samples for pathogenic *Salmonella*, *Enterococcus* and *Aeromonas* bacteria. These data will be useful for interpreting the significance of high concentrations of indicator bacteria in various environmental settings. In addition, these data may be useful for setting Total Maximum Daily Loads (TMDLs), and for evaluating the effect of various sources of bacterial contamination on surface waters.

Monitoring Contaminant Effects in Biota through a Nationwide Program

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Biological organisms respond to the cumulative impact of chemicals in the environment and integrate exposure to those chemicals over time. The Biomonitoring of Environmental Status and Trends Program (BEST) uses a suite of organismal and sub-organismal responses to monitor and assess the effects of environmental contaminants on biota. These methods were selected to respond to a broad range of chemical contaminants and provide a screening-level assessment of impacts, and can help to interpret the significance of chemical exposure data. Using fish and fish-eating birds, BEST has applied these biological response measures in riverine and estuarine environments to characterize and describe habitat quality and organism health as affected by contaminants. Some of the methods used include indicators of the status and function of the immune, reproductive, and endocrine systems, biochemical responses, general measures of organism health, reproductive success, porewater toxicity, and concentrations of organochlorine pesticides, PCBs, and metal, metalloids, and trace elements in tissue. Methods for fish health have been applied at over 80 sites in four major river basins (Mississippi, Columbia, Rio Grande, and Yukon). Porewater toxicity of sediments and TCDD-equivalents (as measured by the H4IIE cell bioassay) in fish tissue were measured at more than 200 sites in estuaries on the Pacific and Gulf coasts. Osprey (*Pandion haliaetus*) reproductive success, contaminant concentrations in eggs, and other biomarkers have been measured in the Columbia River system (including the Willamette River) and in the Delaware River and Bay. Results of this monitoring have identified effects at the organismal level at several locations, suggesting that contaminants are having adverse effects on biota in those areas.

Bioaccumulation and Mobility of Cadmium in Willow and Soils, Alaska—Implications for the Health of Browsing Animals

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As part of a larger project examining the mobility, uptake, and speciation of Cd in subarctic ecosystems, we compare the relative bioaccumulation of Cd by willow (*Salix* sp.) with other common shrub and tree genera. The purpose of this study is to understand the mechanisms by which willow bioaccumulates Cd and ultimately to evaluate the importance of this phenomenon to the health of browsing animals. In addition, we are currently investigating the biochemistry (chemical speciation) of Cd in willow (and supporting soils) using x-ray absorption fine structure (XFAS) spectroscopy.

We collected *Salix glauca* (grayleaf willow) from a number of areas in south-central Alaska growing over lithologic units that varied in total- and extractible-soil Cd. The elevated (mineralized) lithologies included base metal skarns, low-sulfide gold quartz veins, as well as carbonaceous marine shales; non-elevated lithologies included metasedimentary and metavolcanic schists and gneisses. Total Cd concentrations (expressed on a dry weight basis) in willow leaf tissue from mineralized areas were ~17 ppm and for twig tissue ~10 ppm. Plantation-grown willow individuals dosed with 0.18 mM (20 ppm Cd) solutions of Cd-nitrate (with and without the chelates citrate and salicylate) showed similar trends. These values are 5-8 times the Cd concentrations in willow found to be toxic to ptarmigan (grouse, genus *Lagopus*) in Colorado (Larison and others, 2000). The potential for Cd toxicity to grouse, moose, and other browsing animals apparently exists in Alaska in areas naturally high in Cd. Willow from non-mineralized areas in our study had leaf and twig concentrations (n=32) of ~1.0 ppm and 0.78 ppm, respectively. Other shrub species collected at the same sites commonly had <0.04 ppm Cd in their tissues. In both mineralized and non-mineralized areas, Cd concentrations in soils decreased with depth (the organic-rich A1 horizon having nearly four-times the total Cd as the C horizon).

Role of Water-Quality Monitoring for Exposure Assessment in Studies of Breast-Cancer Incidence in Suffolk County New York

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Several areas of Suffolk County, eastern Long Island, New York, have reported clusters of elevated breast-cancer incidence. One postulated cause is exposure to pesticides in drinking water. Ground water, the sole source of drinking water in these areas, is pumped from aquifers that are susceptible to contamination from human sources. The County has a history of agriculture and associated pesticide use, and use of pesticides by homeowners has increased during progressive suburbanization. Since 1997, ground-water sampling by the USGS and Suffolk County Department of Health Services in a cooperative program with New York State Department of Environmental Conservation has revealed the presence of many pesticides in ground water, some of which exceed maximum contaminant levels for drinking water under federal guidelines.

Epidemiological investigation of elevated incidence of breast cancer in several areas in Suffolk County requires a method of assessing exposure to contaminated drinking water and (or) a prospective cohort study. The latter is costly and time consuming. Water-distribution systems in these areas can be modeled upon an approach used by the Agency for Toxic Substances and Disease Registry to study exposure to contaminated drinking water at a childhood leukemia cluster in Dover Township, New Jersey. The Agency used the model EPANET 2.0 to simulate an historical water-supply system. In conjunction with water-quality data from source waters, this model was used to assess environmental exposure to contaminants in drinking water.

This same model could be used to assess the historical exposure to pesticides in drinking water in conjunction with a pesticide database being compiled by the National Institutes of Health for use in studies of breast-cancer incidence through-out Long Island. Assessing exposure to contaminated drinking water on eastern Long Island would integrate the effects of current ground-water quality, historical levels of ground-water contamination, source-water treatment, pesticide degradates, and the toxicological relevance of analytical-detection limits.

Ground-Water Quality and Childhood-Leukemia Cluster Near Fallon, Nevada

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Since 1997, 15 cases of acute lymphocytic leukemia and 1 case of acute myelocytic leukemia have been diagnosed in children and teenagers who live or have lived in an area centered on the town of Fallon, Nevada. In cooperation with the Nevada Division of Health, Centers for Disease Control and Prevention, and Agency for Toxic Substances and Disease Registry, the U.S. Geological Survey sampled 100 wells in the Fallon area in 2001. Twenty-nine of these wells were sampled previously in 1989. Comparison of results for measured constituents for the 29 wells indicate water quality did not substantially change between 1989 and 2001, however, short term transient changes may have occurred that were missed. Statistical comparisons show case families apparently are exposed to the same concentrations of arsenic, uranium, and radon as the rest of the community. Volatile organic compounds were rarely detected in ground-water samples and regulated compounds were consistently at concentrations less than drinking water standards.

Drinking water standards for arsenic sometimes were greatly exceeded; total-arsenic concentrations in 10 percent of the wells exceeded 500 µg/L. In settings where contaminant concentrations greatly exceed standards, homeowners cannot automatically assume home reverse-osmosis systems will lower concentrations to safe levels.

Important radioactive isotopes ingested by Fallon area residents are ^{222}Rn and $^{238/234}$U, and probably ^{210}Po and the immediate decay products of ^{222}Rn (^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po). Isotopic measurements indicate the uranium is natural and not the result of a 1963 underground nuclear-bomb test near Fallon. More than 90 percent of the samples exceeded the proposed MCL for ^{222}Rn. Depending on the radon activity, water that has been stored in a pressure tank overnight may be appreciably more radioactive because of ingrowth than water freshly drawn from the aquifer.

Naturally Occurring Arsenic in Ground Water in Southeastern Michigan: Practical Information from USGS Studies

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In southeastern Michigan, naturally occurring concentrations of arsenic in well-water may exceed 150 micrograms per liter. In cooperation with nine county health departments and the Michigan Department of Environmental Quality, USGS and University of Michigan researchers 1) conducted field investigations, 2) evaluated arsenic concentrations with respect to water-quality parameters, geologic formations and aquifer mineralogy, and 3) prepared geographic datasets and maps depicting arsenic distribution in the study area. These data identified plausible environmental processes leading to elevated well-water arsenic concentrations, and excluded other processes. The study has produced quantitative data to address factors influencing variation in arsenic concentration in single wells. Geostatistical approaches were applied to develop maps depicting the probability of exceeding specific proposed Maximum Contaminant Levels. The data, maps, and spatial datasets produced have been used by well owners, well drillers, public water suppliers, elected officials, and epidemiologists.
Among the more important study findings were:

- The majority of well-water arsenic occurs in the reduced form -- As(III)
- Arsenic concentrations in well water exhibit vertical stratification, with maximum concentrations occurring near the bedrock surface
- Arsenic concentrations range from 6 mg/kg to over 300 mg/kg in aquifer materials in the study area
- There is no correlation between the arsenic concentration in consolidated aquifer materials and the adjacent well water
- Concentrations of arsenic in aquifer water are very reproducible over periods of 10 years or more
- Observed concentrations of arsenic in drinking water from individual wells may be influenced by sampling methods and analytical procedures
- Well construction practices may influence arsenic concentration in individual wells completed in the same aquifer
- In some counties and townships, the median well-water arsenic concentration exceeds the current standard of 10 micrograms per liter, and the probability of finding a suitable ground-water supply is low.

Arsenic Does Not Appear to be the Risk Factor for Bladder Cancer in the Absence of both Humic Acid and High Arsenic Levels (> 350 ug/l)

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BACKGROUND: Since the 1980s, the US risk analyses for arsenic in drinking water have been based on observations from the Blackfoot-Disease endemic area of SW Taiwan where the artesian wells contained humic acids and high arsenic levels (350-2,000 ug/l) and the shallow wells lacked humic acid and had low arsenic levels (0-300 ug/l). Some villages had wells from both sources. Early studies analyzed risk by well source; Later studies analyzed only by mean arsenic level for wells in each village. Both water factors have not been analyzed together.

STUDY DESIGN: We have examined the data underlying the NRC 2000 analysis in order to examine the bladder cancer risks according to water source and then to identify the additional information that was learned from examining the specific arsenic levels within the water source groups.

RESULTS: We found that the bladder cancer mortality risk was not associated with the arsenic level in villages that used either only shallow wells as their drinking water source (10-300 ug/l) or both shallow and artesian wells as their drinking water source (ug/l). We found that only for the artesian wells did the bladder cancer mortality increase with increasing level of arsenic.

CONCLUSION: We find no arsenic-related bladder cancer risk with the exception of villages solely dependent upon humic acid-containing water with high arsenic levels above 350ug/l.

Regional, Seasonal, and Ethnic Differences in the NHANES III Pesticide Epidemiology (PEPI) Study

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The third National Health and Nutrition Examination Survey (NHANES III 1988-1994) collects health and nutrition data for a sample of the U.S. population. Exposure information and pesticide metabolites were analyzed for a sub-sample of 1338 NHANES III participants ages 20 to 59 from 24 locations in 13 states, and 978 people provided urine samples for analysis of pesticide metabolites (ug/L and ug/g creatinine corrected). We describe: the geometric mean, median, interquartile range and 95th percentile for pesticide metabolites by region, season, ethnic differences, and seasonal differences by census region; a higher apparent pesticide burden for respondents in the South and Midwest; a comparison of high urban (>1 million) geographic areas to areas adjacent to urban area (>1 million); a deficit of rural counties or areas with active agriculture; seasonal variation by region, where 1-naphthol and 2,5-dichlorophenol had a higher concentration for the samples taken in the summer; and, provide crop specific pesticide use patterns at the time of the survey for the few predominantly rural counties. Because samples were mainly obtained from highly urban locations, exposures among the rural population living in agricultural areas may be different. Furthermore, sampling did not always occur in high pesticide use seasons in all areas surveyed, limiting our ability to make regional comparisons and possibly underestimating exposures in some areas. Due to the small sample size more data will be needed to confirm these findings, and targeted studies with community HANES on populations in agriculture over multiple seasons.

Estimating Ground Water Arsenic Concentrations For Exposure Assessment In Cancer Epidemiology

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The National Cancer Institute (NCI), in collaboration with the State Departments of Health in Maine, New Hampshire, and Vermont, is conducting a large population-based case-control study of bladder cancer in northern New England to determine the reasons for the elevated bladder-cancer incidence and mortality rates in men and women. One hypothesis is that environmental exposure to arsenic in drinking water may be related to risk of bladder cancer.

A recent USGS and NCI ecological study suggested that bladder-cancer mortality in New England may be associated with private groundwater use, which supports including water source and consumption information in the case-control study. Because of the long latency period associated with bladder cancer, a key problem is assessing past exposure to water contaminants in private wells. Thus, lifetime residential histories will be collected from each subject. The USGS will then sample wells at the former residences for arsenic and other contaminants.

A USGS/NCI/Dartmouth College pilot study showed that exposure histories for many participants cannot totally rely on the sampling of former wells because wells will not be locatable, may be destroyed, or are outside of the study region. Therefore, the USGS and NCI are developing a statistical model to estimate ground water arsenic concentrations based on geologic, hydrologic, and land-use data.

The model will account for spatial and temporal aspects of arsenic contamination and will incorporate geochemical explanatory terms (deterministic models), GIS techniques, and spatial statistics. Groundwater arsenic-concentration data, statewide geologic data, hydrologic data, and anthropogenic factors will be included. By integrating GIS tools with model, arsenic concentrations can be estimated for participants with incomplete addresses.

Application of Health-Based Screening Levels to Ground-Water Quality Data in a State-Scale Pilot Effort

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The U.S. Geological Survey (USGS), as part of its National Water-Quality Assessment Program, has undertaken an interagency study in cooperation with the U.S. Environmental Protection Agency (USEPA), the New Jersey Department of Environmental Protection, and Oregon Health & Science University to develop, test, and refine methods to communicate its water-quality findings in a human-health context. In this state-scale pilot effort, health-based screening levels (HBSLs) are being developed for unregulated compounds (that is, compounds without drinking-water standards) using USEPA toxicity values and USEPA Office of Water methodologies for calculating lifetime health advisories (LHAs) and risk-specific doses (RSDs).

Ground-water samples from 30 public-supply, 82 domestic, and 78 monitoring wells in New Jersey were analyzed for 96 pesticides, 88 volatile organic compounds, and 7 nutrients. Of these 191 compounds, 103 were detected. Measured concentrations of the 44 detected compounds that are regulated in drinking-water supplies were compared to USEPA and New Jersey maximum contaminant levels (MCLs). USEPA guidelines (LHAs or RSDs) for comparison with measured concentrations exist for only 25 of the remaining 59 detected, unregulated compounds; therefore, the ability to interpret the occurrence of 34 unregulated compounds in a human-health context is limited. HBSLs were calculated for 13 of these 34 compounds, increasing the percentage of all detected compounds with human-health benchmarks from 67 to 80 percent. HBSLs were not established for the remaining 21 unregulated compounds because acceptable toxicity values are not available. Concentrations of 11 compounds exceeded human-health benchmarks (8 exceeded MCLs, 1 exceeded an existing LHA, and 2 met or exceeded new HBSLs). Comparisons of detected concentrations to MCLs and HBSLs are being examined in relation to detection frequencies, hydrologic factors, and exposure considerations to determine the potential human-health implications for public and domestic ground-water supplies in New Jersey.

Deriving Crop Maps from Remotely Sensed Imagery To Support Agricultural Chemical Exposure Research

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Exposure to agricultural chemicals has been associated with diseases, such as cancer, adverse reproductive outcomes, and neurological disorders. To study the relationship between agricultural chemical exposure and health outcomes, information is needed on the types of agricultural chemicals that a person may have been exposed to in the past. In particular, epidemiologists have been hampered in their research by the lack of information on historical environmental exposure to agricultural chemicals for rural populations. Traditional methods used by epidemiologists to estimate historical exposure such as, questionnaires and environmental/biological sampling, may not be useful for estimating indirect exposure to agricultural pesticides.

The U.S. Geological Survey (USGS) has been collaborating with the National Cancer Institute in evaluating the potential of remote sensing technology to derive historical crop type information. These maps can then be integrated with other environmental data such as, chemical use, hydrology, and atmospheric data, in a geographic information system model to estimate agricultural chemical exposures. A major problem with using imagery to derive land cover information is the time and expense involved in using traditional image classification methods. Cost-effective classification methods are essential, because studies of rare diseases like cancer must cover large geographic regions and span many decades to determine statistically significant relationships between environmental exposures and disease occurrence.

The USGS is developing advanced image processing techniques to derive land cover information from satellite imagery that will support agricultural chemical exposure research at the National Cancer Institute. A summary of our research to date will be presented using case studies in the Platte River Valley (Colorado and Nebraska) and Iowa.

Improving Beach Management Through Water-Quality Modeling, Geographic Information Systems, and Economic Analysis

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The presence of *Escherichia coli* (*E. coli*) in recreational fresh water, an indicator of fecal contamination, is a growing public health concern worldwide. Recent U.S. Geological Survey (USGS) studies suggest that *E. coli* in beach environments may exhibit spatial and temporal variation that reduces the effectiveness of existing water-quality monitoring programs. Until inexpensive rapid testing methods become available, predictive modeling and visualization are two promising tools for improving beach management. Also, estimates of the health and economic impacts of swim closures are needed to understand and improve policy outcomes.

The results from two ongoing inter-disciplinary USGS projects related to beach and swim-closure policy in Lake Michigan are described here. In the first project, environmental variables collected by the U.S. Environmental Protection Agency in the summer of 2000 are used to model and visualize the variability of *E. coli* at West Beach, Indiana. At present, the best model fit can explain about thirty percent of the variability in *E. coli* levels. Additionally, maps and animations of the data are used to demonstrate how variability reduces the usefulness of closure decisions based on single-sample testing.

In the second project, transfer policy analysis is used to demonstrate the economic values that are created and lost by making correct and incorrect swim-closure choices. For this project, the Indiana Dunes State Park beach is used as a case study. Results show that society might lose three to five times more economic benefit on a day when swimming is prohibited unnecessarily than it gains from avoiding adverse health effects when swimming is prohibited correctly. Thus, the value of reducing incorrect swim closures may be sufficient to justify additional investment in water-quality monitoring. These projects highlight the innovative use of geographic technologies and economic methods in the study of water-quality policy, environmental monitoring, and risk assessment.

Medical Geology: An Emerging Discipline in Support of Environmental and Military Medicine

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"Medical Geology" is defined as the science dealing with the relationship between natural geological factors and health problems in man and animals. Scientists are beginning to assess the influence of natural and anthropogenic earth science factors on the geographical distribution of a wide range of human and animal diseases. Examples of these influences are: classic internationally recognized examples of trace element deficiency (eg, goiter), excess (eg, dental and skeletal fluorosis), and poisoning (eg, chronic arsenicosis). Understanding the potential adverse health effects of geo-environmental factors such as dust, soils and contaminated drinking water is of pivotal importance on the development of programs to maintain force health protection, readiness and biological-environmental surveillance. This presentation will cover these and many other aspects of medical geology studies with particular emphasis on the role of trace elements and toxic metals that affect human health.

Metals are important in environmental health and on the study of human diseases (pathology) because of their potential toxic effect(s) to one or more organs. Exposure to toxic metal ions may occur via three principle routes: percutaneous absorption, ingestion, or inhalation. Dermal toxicity results from local tissue responses through direct contact of the metal with skin, or alternatively, may represent a manifestation of systemic toxicity following ingestion or inhalation. Allergic contact dermatitis induced by nickel (Ni) is an example of a local tissue response. The adverse cutaneous reactions resulting from chronic ingestion or inhalation of arsenical compounds exemplify systemic toxicity.

A variety of toxic pathologic responses in human tissues and organs (i.e., skin, liver, heart, kidney) associated with both acute and chronic exposures to metals have been described.[1-4] The aim of this presentation is to provide examples where both deficiencies of trace elements as well as toxic exposures of metals may be involved in physiologic changes and the development of human diseases. We will discuss the impact(s) of metal ions and trace elements on human health as illustrated with examples of arsenic poisoning from contaminated water in the Bengal Delta (India and Bangladesh) and from coal combustion in southwest China. A brief overview of clinico-pathological aspects of toxic metal exposures including selected skin lesions will be presented.

Telemedicine – Emerging Technology for Health-Related Research

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Within the last 5 years, a number of factors have combined to make telemedicine a powerful and cost-effective tool for healthcare delivery and medical research, including the global penetration of the Internet and associated broadband technologies, the development and wide availability of inexpensive digital imaging equipment, and the concomitant increase in processing power and decrease in cost of commercially available computers.

The Armed Forces Institute of Pathology's electronic consultation center is the largest of its kind in the world, expediting the AFIP's pathology expertise to 145 contributing institutions around in the world in the areas of telepathology, telecytology, teleradiology, and teleforensics. Telemedicine consultations are processed within an average of 3.2 working hours, and the institute has shown a 97%+ rate of clinically important concordance between electronic and traditional glass-based diagnosis.

The Department supports a wide range of platforms and currently receives cases in three distinct paradigms: static images (comprising 94% of cases in 2002), robotic microscopy, and whole-slide digital images. Advanced technologies (whole-slide images, robotic microscopes) provide excellent diagnostic quality and allow the pathologist to view any region of a slide at any magnification.

In 2002, 10% of our caseload was diagnosed using robotic microscopy. This form of telepathology consultation uses the Internet as the transport paradigm for diagnostic consultation, with the AFIP consultant controlling the microscope (adjusting field of view, focus, illumination, etc.) at a significant distance from the specimen itself. Routine diagnostic consultations are routinely completed across up to 7 time zones.

Whole-slide images, digital scans of entire glass slides, remain in the evaluation and proof-of-concept phase in 2002; however we anticipate receiving these images for consultation as early as 2003. We are currently utilizing this tool for educational purposes as part of the Institute's commitment to distance learning.

Static images, while limiting to the pathologist in terms of diagnosis, are extremely portable and cost-effective; and may be efficiently utilized in a globally-distributed research setting. Guidelines for appropriate use of static images in the area of pathology will be emphasized.

Rapid Assessment of an Urban Hazard: Spectroscopy of the World Trade Center Dust

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On September 16th, 2001, five days following the collapse of the World Trade Center Towers, hyperspectral data was collected over ground zero with the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS). Our intent was to rapidly assess the asbestos hazards of the dust that blanketed a large portion of lower Manhattan. Within two days of the overflight, a two person team had collected ground samples of the dust and airfall debris from 35 sites within a 1- km radius of the collapse site including samples from two indoor locations unaffected by rainfall and samples of insulation from two steel beams at ground zero. Spectral measurements of dust-free cement pavement on the top level of a parking garage in New Jersey, located 3 km west of ground zero, were used to calibrate the AVIRIS data prior to spectral mapping with the USGS Tetracorder spectral identification algorithm. The dust and beam-insulation samples were analyzed for a variety of mineralogical and chemical parameters using reflectance spectroscopy, scanning electron microscopy, X-ray diffraction analysis (XRD), and chemical leach tests.

AVIRIS mineral maps do not show widespread distribution of chrysotile or amphibole asbestos above the few-percent detection limit of the instrument at the ground surface, but do show a few isolated pixels of potentially asbestiform minerals. AVIRIS images were also used to locate hot spots in the debris pile hidden from view by smoke, thus allowing firefighters to more effectively battle the fires. Delivery of this information to emergency managers within two weeks of the attack demonstrated how rapidly these urban hazards could be assessed on a spatially-comprehensive scale with imaging spectroscopy. Spectral and XRD analysis of the field samples took several weeks longer and revealed that trace levels of chrysotile were present in 2/3 of the dust samples but at concentrations lower than 1wt%, well below the sensitivity level of AVIRIS. The field data suggest that trace levels of chrysotile were distributed with the dust radially in west, north, and easterly directions perhaps to distances greater than 3/4 km from ground zero. The lack of chrysotile at levels above the detection limits of both methods in all but one sample collected south of ground zero may indicate that chrysotile was not distributed uniformly during the collapse.

National and New Jersey Statewide Reconnaissance Surveys of the Occurrence of Radium-224 in Public Ground-Water Supplies

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Variations in gross alpha-particle radioactivity observed in water from aquifers in New Jersey within the first 3 days after sample collection cannot be explained by variations in the concentration of radium-226. A previously undetermined radionuclide, radium-224 (Ra-224), with a 3.64-day half-life was found to be responsible. Because Ra-224 may pose an additional health risk not addressed by the U. S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) of 5 pCi/L (picocuries per liter) for combined radium (defined as radium-226 plus radium-228) in drinking water, the U.S. Geological Survey (USGS), in collaboration with the USEPA, the American Water Works Association, and the American Water Works Service Company, conducted a targeted national reconnaissance of radionuclides in public ground-water supplies. Concentrations of Ra-224 exceeded 1 pCi/L in 30 percent, 5 pCi/L in 15 percent, and 10 pCi/L in 5 percent of the 99 samples; the maximum concentration of 73.6 pCi/L was measured in a sample from the Coastal Plain of Maryland. Concentrations of Ra-224 generally were greater than those of other isotopes of radium. Concentrations were greatest in water from the Atlantic Coastal Plain and Interior Lowlands Provinces.

In a related study, the USGS, in collaboration with the New Jersey Department of Environmental Protection, Richard Stockton College of New Jersey, and the New Jersey American Water Company, is conducting the first reconnaissance survey of the occurrence of Ra-224 at a statewide scale in New Jersey. Results of this nearly completed study indicate that concentrations of Ra-224 exceeded 1 pCi/L in 34 percent and 5 pCi/L in 3 percent of the initial 61 samples, with a maximum concentration of 6.8 pCi/L. Concentrations of Ra-224 were greatest in the acidic water in the unconfined Coastal Plain aquifers, where the combination of aquifer characteristics (permeable, coarse-grained, and quartzose), geochemistry (acidic), and land-use (agriculture with nitrogen-bearing leachate that increases acidification) affects the concentration of Ra-224. In this way, local scale (statewide or smaller) studies can help to elucidate the effects of geologic, hydrologic, and geochemical factors on Ra-224 occurrence.

Dusts Deposited by the September 11, 2001, World Trade Center Collapse: Their Chemical Reactions with Simulated Rain Water and Body Fluids

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As part of an environmental study of the World Trade Center (WTC) area after September 11, 2001 (http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-01-0429/), we characterized the chemical composition and reactivity of dusts deposited by the WTC collapse. We analyzed samples of dust deposits from 2 indoor and 15 outdoor locations around lower Manhattan, most collected on September 17 and 18, 2001. The chemical makeup of the dusts integrates chemical contributions from particles of glass fibers, concrete, gypsum wallboard, window glass, metals, paper, paints, lighting, wires, pipes, fire retardants, computers, electronics, and other materials typical in office buildings. Concentrations of some metals in the dusts (zinc, barium, lead, copper, chromium, molybdenum, antimony, and titanium) are higher than in many natural soils. Leach tests using water (1:20 g dust/ml deionized water, 5 min) show the dust samples are quite chemically reactive, and produce alkaline to caustic leachate solutions by dissolving calcium hydroxide from concrete particles. Indoor dust leachates are substantially higher than outdoor dust leachates in both pH (11.8-12.4 versus 8.2-10.4) and alkalinity (500-600 mg/kg versus 20-50 mg/kg). Although they generate caustic alkalinity, the indoor dusts are not as caustic as drain cleaner. Reactions of the dusts with carbonic acid in rain or other moisture help make them less caustic. Leach tests with simulated lung fluids (SLF) (1:20 g dust/ml SLF, 24 hr) produced smaller pH shifts due to the pH-buffering capacity of SLF components. Some metals in the dusts (silica, aluminum, chromium, antimony barium, copper, zinc, cobalt, and nickel) are soluble in water, and many are even more soluble in SLF due to chelation by chloride, citrate, and glycine. This information can be used to help interpret potential origins of health problems that developed in individuals exposed to WTC dust on and after September 11, such as WTC cough, bronchial hyperreactivity, and gastroesophageal reflux.

Mineralogical, Geochemical, and Toxicological Variations of Asbestos Toxicological Standards and Amphibole Samples from Libby, MT

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It is well known that exposure to asbestiform mineral dust is associated with lung diseases such as asbestosis, malignant mesothelioma, and bronchogenic carcinoma. Past attention focused primarily on human exposure and health effects of commercial asbestos. In recent years, there has been renewed recognition of the potential deleterious health effects of asbestos that may occur as accessory minerals in rocks (e.g. serpentinite, a common rock in the US) and in some mineral commodities used in consumer products (e.g. vermiculite or talc). Within the past decades, many *in vitro* and *in vivo* studies have shown asbestos to be cytotoxic and mutagenic, yet the mechanisms responsible have escaped identification. It is believed that asbestos-related diseases may be a result of two mechanisms, mechanical and intracellular. Evidence in the literature indicates that the potential for the asbestiform minerals to elicit one or both of these mechanisms may be based on the mineral's mineralogy, size, shape, chemistry, elemental speciation, and electral properties. However, contradictory evidence can also be found in the literature about the specific mechanism of toxicity attributed to specific asbestiform minerals. Thus, the mechanistic questions can be best answered through increased collaborative research between the geochemistry and health-related communities.

One key step in the collaborative research process is the mineralogical and geochemical characterization of existing and new asbestos standards for toxicological studies. Thus, the USGS has analyzed 5 sets of asbestos standards (5 amosites, 4 anthophyllites, 6 chrysotiles, 5 crocidolites, 4 tremolites) and samples of Libby asbestos. Chemical analyses indicate that elemental content varies between asbestos standards of the same mineral. Analysis (XRD, SEM, EDS) also indicates differences in asbestos habit (particle shape) and the presence of other minerals as contaminants between different asbestos standards, within the sets of asbestos standards and within the Libby samples. Geochemical solubility studies in simulated lung fluids and cell line media containing fetal bovine serum revealed additional variations with these test samples. The level of toxicological indicators varied within each group as well. The Libby, MT amphibole exhibited a higher level of toxicity as compared to the toxicological standard. These variations between the asbestos standards, or those within the sets of the same asbestiform mineral, may be responsible for conflicting toxicological results, ultimately inhibiting mechanistic identification. This work shows the necessity for continuous collaborative efforts between the geochemistry and health-related communities.

Health Risks from Mercury Exposure in Gorlovka, Ukraine

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Mercury exposure presents a significant threat to human health, with documented effects on the nervous, renal, and cardiovascular systems. Geologic enrichment of mercury in coals produced in the Donets Basin of Ukraine has resulted in widespread elevation of mercury levels in the environment due to coal combustion. In Donetsk, the largest city in the region, mercury concentrations in soils locally exceed background levels by factors of one to two thousand, and the average content of mercury in Donetsk air is about 15-20 times background. The city of Gorlovka (population 320,000), 50 km northeast of Donetsk, is located in the central portion of the Donets Basin, where coals have had the highest mercury contents in the region. The city limits of Gorlovka also contain the abandoned mine workings at Nikitovka, a world-class mercury deposit where over 30 thousand metric tons of mercury were produced. The workings at Nikitovka consist of a series of open-pits, extensive mine tailings and tailings ponds, and an abandoned mercury processing plant, all of which are uncontrolled and readily accessible. Mercury vapor concentrations near the Nikitovka processing plant are hundreds of times background levels. Reconnaissance sampling of coal produced as a by-product during the lifetime of the Nikitovka mines gives mercury contents more than 100 times the average mercury content of U.S. coals.

Health statistics for residents of Gorlovka remain largely unavailable. The proximity of Gorlovka to millions of metric tons of untreated waste from an abandoned mercury deposit, together with continued use of mercury-rich coal in local industries, make it very likely that a portion of its population is being exposed to unhealthful levels of mercury. High concentrations of mercury were found in urine, blood, and bones of children in a previous study of two Gorlovka schools. Additional work is needed in Gorlovka to document health effects, confirm mercury exposure in individuals, and map out mercury levels in residential areas.

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Mapping the Spread of West Nile Virus and Assessing the Risk of Human Illness

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Since it was first detected in New York City in 1999, West Nile (WN) virus has spread coast-to-coast, having been found in 43 States from Maine to California. The U.S. Geological Survey is working with the Centers for Disease Control and Prevention (CDC) to learn the current geographic extent of the WN virus, to understand how it moves between birds, mosquitoes, and humans, and to predict future outbreaks of the virus.

A collaborative 3-year research project is being conducted on U.S. Fish and Wildlife Service, National Park Service, other Federal lands, and on State, local, and private lands along the Atlantic and Mississippi Flyways. This study uses the sampling of migratory and local wild birds to detect the presence of WN virus and identify possible avian carriers. Over 9,700 birds of more than 150 species have been captured, sampled, and released at 20 Federal and 3 other sites in 12 States during the spring and fall bird migration seasons of 2001 and 2002. A parallel study, being conducted with CDC, is examining the distribution and number of mosquito species in relation to land cover, weather conditions, and avian mortality. Systematic mosquito surveillance (weekly collections at seven sites) is being conducted year-round in St. Tammany Parish in Louisiana, complementing avian collections done at Bogue Chitto and Big Branch National Wildlife Refuges in the parish. Finally, West Nile virus surveillance data from the CDC is being studied to determine the spatial and temporal relationships between disease outbreaks in birds and animals and human illness. Information from these analyses will guide the creation of predictive models of disease risk.

These surveillance systems provide the basic information on the “geography” of the virus. Combining these data with information about avian migratory patterns, landscape characteristics, and weather conditions, over space and time, will provide the foundation for developing spatial analytical and forecasting models to assess the risk of human illness.

Ambient Shoreline Sources of *E. coli* in a Coastal Beach and Stream of Southern Lake Michigan

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Swimming advisories due to excessive *Escherichia coli* concentrations are common along marine and freshwater coastlines. Research into sources, movement, and persistence of *E. coli* has been frustrated by oversimplified paradigms and inability to account for contributing causes of contamination. The author reviews his research at 63rd Street Beach, Chicago, IL and Dunes Creek, a coastal stream in Indiana to illustrate how intrinsic sources of E. coli can influence water quality and consequently compromise the use of E. coli as an indicator species of pollution.

An intensive study was undertaken at 63rd Street Beach to characterize the source and fate of *E. coli* in beach water and sand at the beach. From April through September 2000, water and sand samples were collected daily or twice daily at two depths, three consecutive days a week (water n=1747, sand n=858); hydrometeorological conditions and bird and bather distribution were also recorded. *E. coli* in sand and water were significantly correlated, with concentration in foreshore sand highest followed by submerged sand and water of increasing depth. Gulls contributed to part of the *E. coli* in the sand and water the following day. *E. coli* recolonized newly placed foreshore sand within two weeks. ANOVA, correlation, cluster analyses, concentration gradients, temporal-spatial distribution, demographic patterns, DNA fingerprinting, and *in vitro* and *in situ* growth observations suggest that *E. coli* may be able to sustain population density in temperate beach sand during summer months without external inputs.

Dunes Creek is a small coastal stream that drains wetlands and aquifers and empties onto a Lake Michigan beach at the Indiana Dunes State Park. Elevated counts of *E. coli*, which are mostly attributable to non-point sources, have been a persistent problem in the creek and contiguous bathing water at the beach near its outfall. Spearman analysis showed a correlation between creek water and stream sediment, stream sediment and shoreline, shoreline and 1 m inland.. Median *E. coli* was highest in stream sediments followed by, in order of magnitude, bank sediments, spring sediments, stream water, and isolated pools; in forest soils, *E. coli* counts were low but high outliers were common. Sediment moisture was correlated with *E. coli* counts ($p = 0.001$, $n = 34$). These studies clearly suggested increased ditching, stream order, erosion of riparian sediment, and loss of wetlands may account for higher bacterial density. *E. coli* was ubiquitous in Dunes Creek and associated basin.

These examples present evidence that creek and lake shores may 1) play a major role in bacterial water quality, 2) be important non-point sources of *E. coli* to water rather than a net sink, 3) be environmentally, and perhaps hygienically, problematic, and 4) be capable of supporting an autochthonous, high density of indicator bacteria for sustained periods, independent of lake, human, or animal input. Potential ambient growth and persistence of *E. coli* in soils, sediments and macrophytes associated with temperate waters is poorly investigated.

Bank Filtration of Waterborne Pathogens, Platte River, Nebraska

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Bank filtration has been used for centuries to purify river water used as drinking water. However, recent efforts to protect against such waterborne pathogens as *Cryptosporidium* and *Giardia* mandate the quantification of bank filtration efficiency so that drinking-water systems can receive credit for this natural removal mechanism. Because *Cryptosporidium* and *Giardia* oocysts are commonly present in river water, ineffective removal by bank filtration could result in increased health risks. Methods to detect *Cryptosporidium* and *Giardia* oocysts can be unreliable and cost prohibitive relative to standard biological tests. Limitations of detection methods mean that failure to detect oocysts in drinking-water supplies does not insure their absence in the water. Water-quality indicators that are correlated to the presence of *Cryptosporidium* and *Giardia* oocysts can be helpful in reliably determining contamination by waterborne pathogens, while at the same time alleviating the financial burden on the drinking-water system of paying for direct analyses.

A study is currently underway by the U.S. Geological Survey, in cooperation with the City of Lincoln and the U.S. Environmental Protection Agency to evaluate the potential for transport of microorganisms of varying sizes through bank filtration to a public-water supply during different seasons and flow regimes of the Platte River. Samples are collected during base-flow conditions and significant runoff events from surface water, one collector well, treatment plant effluent, and treated drinking water. These samples are then analyzed for *Cryptosporidium* and *Giardia*, temperature, dissolved oxygen, specific conductance, and pH, turbidity, particle counts, dissolved organic carbon, hydrogen and oxygen isotopes, total coliform and *E. coli*, aerobic spores, algae, diatoms, and male-specific and somatic coliphages. Results and implications of these analyses will be discussed.

Mycobacteriosis and Striped Bass

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Mycobacteriosis is a bacterial disease in which striped bass (rockfish) may be disfigured as a result of skin ulcers and internal lesions. The bass may also be skinny due to the chronic nature of this wasting disease. The total extent to which the disease is occurring along the Eastern seaboard in unknown but the disease has been reported from stripers taken from the Chesapeake and Delaware Bays. During 1998-99, the skin ulcers attributed to mycobacterial infection were observed in up to 50% of the striped bass from some Virginia tributaries of the Chesapeake. Data obtained during the summer of 2001 from fish harvested in Virginia waters indicated that, at least in some areas, up to 70% of striped bass may be infected with the mycobacteria that are associated with the disease. Given the persistence of this mycobacteriosis outbreak (at least four years), this does not appear to be a short-term problem. Several *Mycobacterium* spp., obtained from the skin, kidneys and spleens of Chesapeake Bay striped bass have recently been isolated and characterized. Included were *Mycobacterium* spp. not previously known to be fish pathogens and *M. marinum* a species associated with pathology in striped bass and numerous species of aquarium fishes. Many acid-fast bacteria, including some that commonly infect fishes, such as *Mycobacterium marinum, M. fortuitum*, and *M. chelonei,* can cause infections in people and therefore are a human health concern. This is not a trivial consideration. Fish handler's disease attributed to mycobacterial infection is not uncommon in the Chesapeake Bay region. The striped bass is a highly prized target species for both recreational anglers and commercial fishermen. Because we have isolated opportunistic pathogenic mycobacteria from striped bass skin ulcers, the potential for contact between people and the microorganisms may be very high.

The Huntington Beach Investigation: Where are the Bacteria from?

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The central Southern California Bight is an urbanized coastal ocean that is heavily impacted by material discharged from land-based sources in the region (e.g., marshes, storm drains, rivers, ocean sewage outfalls). For most of the summer of 1999, large sections of Huntington Beach, on the southeastern edge of San Pedro Bay, were posted or closed due to bacterial contamination. The beach has continued to be posted or closed in the summers of 2000-2002. The sources of the contamination were unknown. One hypothesis was that cross-shelf transport processes, in the stratified summer season, might move material from a local outfall, 4 km offshore at the shelf break, into the near-shore. In order to test this hypothesis, 13 moorings that included 7 upward-looking ADCPs and temperature and/or salinity sensor arrays were deployed across the shelf for 4 months in the summer of 2001.

Semidiurnal internal tides were the dominant processes that transported water and material suspended below the thermocline across the shelf. The shoaling of these internal waves allowed the cold water from below the thermocline into water depths less than 15 m. Cross-shelf transport processes were inhibited in water depths less than 10m, but cooler pulses were occasionally observed in the near-shore. However, the near-shore cold water events did not correlate with beach contamination. Other processes that are suspected to be related to bacteria contamination on Huntington Beach during the summer months will also and discussed.

Poster Abstracts

Arsenic and Metals in Soils in Residential, Forest, Orchard, and Industrial Areas of the Coastal Plain, North-Central New Jersey

By Julia L. Barringer[1], Zoltan Szabo[1], and Thomas H. Barringer[1]
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Concentrations of arsenic exceed the State Cleanup Criterion of 20 ppm (parts per million) in both sandy and clay-rich soils of two residential areas, one adjacent to (area 1), and a second 0.5 mile from (area 2), a Superfund site in north-central New Jersey. Arsenic concentrations much greater than 20 ppm were measured in soils at the Superfund site, where arsenical pesticides were produced during 1917-45. Identification of the Superfund site as a source of arsenic to residential soils was confounded by the presence of arsenic-bearing minerals in the geologic substrate and the past use of arsenical pesticides in the orchards on which the residential developments were built. In a cooperative study with the U.S. Environmental Protection Agency and the New Jersey Department of Environmental Protection, the U.S. Geological Survey collected samples from discrete soil layers (horizons) in nearby forested areas, in former and current orchards, at the Superfund site, and in the residential areas; these were analyzed for 23 metals and total organic carbon. The chemical (arsenic and metals) “signatures” of near-surface soils from forests (geologic and atmospheric contributions), orchards (pesticide use), and the Superfund site (industrial inputs) were determined statistically and graphically and compared with the signatures of near-surface soils from the residential areas. The chemical signatures of soils from forests, orchards, and the Superfund site were distinctive. The signature of soils from area 1 was similar to that of soils from the Superfund site; soils from both area 1 and the Superfund site contained similar slag and debris. The signature of soils from the more distant area 2 was similar to that of orchard soils, indicating that arsenic levels of environmental concern in residential soils of the region derive from multiple sources. More widespread measurement of soil arsenic in New Jersey has since ensued.

A Field Test Kit To Identify Arsenic-Rich Coals Hazardous to Human Health

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Domestic combustion of mineralized coal in southwestern Guizhou Province, China has caused arsenic poisoning. The predominately rural population in this mountainous region uses coal for residence heating and food preparation including drying of food stuffs over open, unvented fires. Coal in some parts of this region is extraordinarily enriched in As, Sb, Au, and Hg. The use of high-arsenic coals has caused in excess of 3000 cases of arsenic poisoning in several villages. Local Public Health Officials have tried to develop a field arsenic test procedure to identify potentially hazardous coals but the results may have been unreliable by the chemical inference of sulfur in the test procedure. We have adapted a highly sensitive *Hach* arsenic-in-water field kit for the analysis of arsenic in coal. Concentrated sulfuric acid in used to dissolve a small, powdered, representative coal sample at boiling water temperature. Any sulfide present is oxidized to sulfate to prevent interference. The arsenic is converted to arsine gas and the concentration is determined by comparison of a test strip to a color chart. The effective concentration range is from 0 to1600 ppm.

The systematic use of this arsenic-in-coal test kit by local Public Health Officials should help identify arsenic-rich (>100 ppm) coals deemed hazardous to human health. Identification and closing of the mining of these arsenic-rich coals should help mitigate the endemic arsenic poisoning present in southwestern Guizhou Province.

Medical Geology of Selenium in Rural China

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The relationship between geology and health can be profound in developing countries where the rural population tends to be poor and is living in relative economic isolation. China suffers from the occurrence of human disease caused by both the deficiency and the excess of dietary selenium (Se). Although Se is an essential trace element necessary for human health, it has a relatively narrow range of concentration for optimal well-being. Specific human health hazards related to Se deficiency include Keshan Disease (chronic cardiomyopathy: heart muscle disease) and Kashin-Beck Disease (endemic osteoarthropathy: painful swelling of the joints). Kashin-Beck Disease has a long historical record with references to it dating back to the 8th century BC. Selenium toxicity in humans is characterized by dermatologic lesions, and hair and nail abnormalities. The occurrence of these various diseases is related to the Se concentration in the soil and can also be influenced by groundwater depleting the soils. For example, large areas of China are underlain by loess which has a paucity of Se that weathers to a soil which reflects this deficiency. Smaller areas in China are underlain by metal-rich black shales producing local soils containing relatively high concentrations of Se. Crops, and livestock eating local vegetation, will tend to mirror the Se content of the soil. Poor, rural subsistence-farming populations living in these areas have little or no availability of foodstuffs from other areas. Recognizing the etiology of these diseases, China has tried to mitigate their incidence by providing Se supplements to Se-deficient populations or by limiting agriculture in Se-rich soils.

A Model for Projecting Asthma Statistics on Schools

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1998 National Health Interview Survey data of asthma prevalence were stratified by age, race, and gender and synthesized with Chicago Public School demography from the Department of Education's Common Core of Data for the same year. The results of the small area analysis were brought into an address matched Geographic Information System of schools for visual interpretation. An initiative is under way to develop similar estimates of asthma in a national set of schools.

Modeling the Habitat of Soil-Borne Human Pathogens with a Spatial Fuzzy System

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Spatial data are essential to modeling the habitat of soil-borne human pathogens. These spatial data include soil and geologic mapping, topographic data, soil geochemical data, weather data, and remotely sensed data. Inherent in these spatial data are a number of problems, including gradational spatial boundaries and variability in the precision of the data. Modeling means that relationships between the data and the occurrence of a soil-borne pathogen must be understood or developed. Often, there is no analytical model of this relationship and there are insufficient data for statistical analyses. Rule-based expert systems can provide a framework for input and refinement of expert knowledge in attempting to model the habitat of soil-borne human pathogens. Spatial fuzzy systems extend rule-based expert systems to allow for the numerical modeling of widely diverse and imprecise knowledge in a systematic way. Linguistic expert opinion can be incorporated into the model with numerical data of varying precision. A model objective is to reduce the system to the fewest number of variables necessary for acceptable modeling.

Our spatial fuzzy system, used to model the occurrence of a soil-borne human pathogen, first fuzzifies the input data. Special rules, called fuzzy associative memories, then relate the spatial data to the occurrence of the pathogen. These rules are combined using fuzzy inference and then defuzzified. The result is a numerical fuzzy habitat suitability index for the soil-borne human pathogen. A spatial fuzzy system was used to model the habitat of *C. immitis*, the etiological agent of coccidioidomycosis, in Organ Pipe Cactus National Monument, Arizona. The results of this model may help mitigate further cases of coccidioidomycosis in the Monument by allowing land use managers to avoid the placement of facilities in areas with a high *C. immitis* fuzzy habitat suitability index.

Medical Geology and Public Health: Chronic Arsenic Poisoning Natural History, Toxicity, and Health Effects

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Arsenic is a ubiquitous element in the earth's crest. It is transported in the environment mainly by water, although other natural and anthropogenic sources of exposure to arsenic including burning of arsenic-rich coal, mining and smelter activities are of increasing concern. Issues to be considered in health based risk assessment from arsenic include the speciation, bioavailability and the nature of dose-response curve. Although arsenic has been long known to be carcinogenic to humans, the full extend of arsenic-health related problems has still to be fully identified and studied. Pigmentation and keratosis of the skin are the two most common health effects arising from chronic arsenic exposure. Research has also pointed out significantly higher standardized mortality rates and cumulative mortality rates for cancers of the bladder, kidney, skin, liver and colon in many areas with chronic arsenic pollution. Although several epidemiological studies have documented the sources of exposure and the global impact of arsenic contamination; the mechanisms by which arsenic may induced health effects, including cancer, are not well characterized. Further research is needed to provide a better understanding of the pathobiology of arsenic-induced diseases and to better define the toxicologic pathology of arsenic in various organ systems.

To understand the health effects of arsenic, it is imperative to develop chemical, toxicological and analytical approaches that provide accurate, precise and fast identification of its molecular and metabolic forms. In humans, detoxyfication of arsenic takes place by the methylation of arsenite in the liver to produce monomethylarsonic acid (MMA) and subsequently dimethylarsinic acid (DMA). It has been suggested that the ratio of MMA or DMA to inorganic arsenic (As^{3+} and As^{5+}) may provide a marker to evaluate health based risk of arsenic-induced toxicity. The work reported here provides and discuss important information by which to describe the underlying analytical toxicology,[1] pathology[2] and nature of arsenic-induced lesions.[3] Such information is critical for understanding the magnitude of health effects associated with arsenic exposure throughout the world.

Environmental Mapping with Imaging Spectroscopy of the World Trade Center Area after the September 11, 2001 Attack

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The Airborne Visible / Infrared Imaging Spectrometer (AVIRIS), a hyperspectral remote sensing instrument, was flown by JPL/NASA over the World Trade Center (WTC) area on September 16, 18, 22, and 23, 2001. A 2-person USGS crew collected samples of dusts and airfall debris from more than 35 localities within a 1-km radius of the World trade Center site on the evenings of September 17 and 18, 2001. The AVIRIS data, field spectrometer data collected in areas away from the WTC, and information derived from field samples in and around the WTC were used to calibrate, provide ground truth, and map the debris and its composition in the lower Manhattan area with 2x4-meter sampling. Laboratory analyses and the AVIRIS mapping results indicate the dusts are variable in composition, both on a fine scale within individual samples and on a coarser spatial scale based on direction and distance from the WTC. Replicate mineralogical and chemical analyses of material from the same sample reveal variability that presumably is due to the heterogeneous mixture of different materials comprising the dusts. The spatial variability is observed at large scales of tens of meters to centimeter and smaller scales. AVIRIS mapping suggests that materials with higher iron content settled to the south-southeast of the building 2 collapse center. Chrysotile may occur primarily (but not exclusively) in a discontinuous pattern radially in west, north, and easterly directions, perhaps at distances greater than 3/4 kilometer from ground zero. Although only trace levels of chrysotile asbestos have been detected in the dust and airfall samples studied to date, the presence of up to 20 volume % chrysotile asbestos in material coating steel beams in the WTC debris, and the potential areas indicated in the AVIRIS mineral maps, indicate that asbestos can be found in localized concentrations.

Reflectance Spectroscopy as a Rapid Assessment Tool To Detect Asbestiform Mineralogy: Lessons from the Libby, Montana Region and World Trade Center

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The vermiculite mineral deposit near Libby Montana is also a source of amphibole asbestos. The vermiculite was mined and processed for use as insulation and as additives to potting soil and other applications. Asbestos contamination in the Libby region is currently a concern of the EPA. Possible contamination covers a large region. The EPA and its contractors have identified an area of tens of square miles where testing is desired, involving many thousands of samples.

Detection of amphibole asbestiform contamination can be difficult in certain situations. In the case of Libby vermiculites, amphibole fibers have sometimes grown between vermiculite layers. The index of refraction of vermiculite and the tremolite-richterite-winchite fiber compositions are nearly identical, making it difficult to detect the embedded fibers with normal optical microscopy methods. Methods such as TEM and SEM examine the surfaces and do not probe inside the vermiculite flakes. In other cases, the fibers may be too small to easily detect with standard EPA optical microscopy methods such as Polarized Light Microscopy. Finally, with so many samples needing characterization, a low cost, rapid method is needed to detect the amphiboles. Reflectance spectroscopy potentially fits this need, provides a rapid measurement (few seconds) on unprepared samples and can probe inside materials opaque to other methods. Reflectance spectroscopy can be used in the lab, in the field, and from aircraft and satellite, enabling micro- to macroscopic assessment to be completed. Reflectance spectroscopy was used in assessing the presence Chrysotile in World Trade Center dusts, and is currently being used to study the Libby, Montana region to detect amphiboles.

Application of Physiologically Based Extraction Tests to Assessment of Human Health Impacts From Coal Dust

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The mining and processing of coal releases fine-textured material into the biosphere and contaminants present in the coal are a potential health risk to humans. Exposure pathways of particular concern include ingestion and inhalation. Direct consumption of soil by inadvertent geophagy, is a particular health risk to children because of their high object mouthing rates. The consumption of meat from animals ingesting coal and/or soil during grazing and feeding also represents an indirect exposure pathway for humans. Physiologically based extraction tests offer a means of predicting the uptake of potentially toxic contaminants in coal dust and contaminated soils into human or other animal tissue. These extractions are receiving considerable attention in risk assessments associated with Superfund and other hazardous waste sites.

We have sampled coal from the Donbas region of Ukraine and have completed an assessment of the bioaccessibility of metals from these materials, *i.e.*, the fraction of the metals solubilized from the coal under simulated gastrointestinal tract conditions. *In vitro* extraction procedures have been shown to correlate well with *in vivo* results of oral bioavailability in immature swine (experimental models for human children). A two-step simulated digestion procedure (at 37˚C) was used; the first phase, a simulated gastric digestion using a buffered HCl and glycine solution at pH = 1.5 was immediately followed by a simulated intestinal extraction phase of 0.5M $NaHCO_3$, pH 5.5-6.0. The priority pollutants (Cr, Pb and Zn) were analyzed in the digests. In addition to the Donbas coal, certified reference materials (NIST soil and USGS coals) were also processed using the gastrointestinal extraction procedures. While present efforts are focused on coal dust, we plan to extend these bioaccessibility studies to coal combustion products such as fly ash and burning spoil-pile ash.

Predictive Models for *Escherichia coli* at Ohio Bathing Beaches

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Because current methods using antecedent *Escherichia coli* (*E. coli)* concentrations to assess recreational water quality take at least 18 hours to complete, the sample results may not reflect actual conditions. To address this problem, the U.S. Geological Survey conducted a study during 2000 and 2001 at six Lake Erie beaches and one inland lake in Ohio with the goal of developing models for predicting current bacterial water-quality conditions.

Environmental and water-quality factors related to *E. coli* concentrations were used as explanatory variables in beach-specific multiple-linear regression models. For Lake Erie beaches, factors included wave height, number of birds on the beach at the time of sampling, lake-current direction, rainfall, turbidity, and streamflow. For the inland lake, factors included date, wind direction and speed, and rainfall. The probability of exceeding the Ohio single-sample bathing-water standard for *E. coli* (235 colonies per 100 milliliters) was used as the model output variable because the prediction errors in the models were too large to accurately estimate concentrations of *E. coli*. Based on examination of model predictions and observed *E. coli* concentrations, threshold probabilities were selected to aid the determination of when water-quality was likely to be impaired. Computed probabilities that are less than a threshold probability indicate to the beach manager that bacterial water quality is likely acceptable; computed probabilities above the threshold probability indicate that the beach should be posted with a water-quality advisory.

The models and selected thresholds will be applied in 2002 to determine how well predictions of impairment compare to current methods for assessing recreational water quality. If, over time, the probability-based models predict impairment of recreational water quality as well as or better than current methods, beach managers may consider using the models to aid in decisions on posting beach advisories. This would provide more timely and accurate assessments to the public.

Concentrations of *Escherichia coli* in the Swash Zone at Four Ohio Bathing Beaches

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This study was done in cooperation with the Ohio Water Development Authority, Northeast Ohio Regional Sewer District, Ohio Lake Erie Office, Cuyahoga County Board of Health, Cuyahoga County Sanitary Engineers, and Cuyahoga River Community Planning Organization.

The zone of the shoreline that is washed by waves or tides, called the swash zone has been suggested as a possible habitat for waterborne pathogens. To investigate this possibility, the U.S. Geological Survey determined the distribution of *Escherichia coli* (*E. coli*) in subsurface sediments and interstitial waters collected from near the swash zone ("swash-zone materials") at three Lake Erie beaches and one inland lake during 2000 and 2001. Water and lake-bottom sediment samples were also collected from within the bathing areas and analyzed for *E. coli*, and the bathing-water data were compared to swash-zone data to determine whether swash-zone materials were enriched with *E. coli*.

Wide ranges of *E. coli* concentrations were found in swash-zone materials. Concentrations of *E. coli* in interstitial waters ranged from less than 3 to 400,000 colonies per 100 milliliters; in subsurface sediments they ranged from less than 1 to 30,000 colonies per gram dry weight of sediment. Median concentrations of *E. coli* were higher in subsurface sediments collected near the swash zone than in lake-bottom sediments collected within the bathing areas at two of the four beaches. Concentrations of *E. coli* in interstitial waters collected on the same date and about 100 feet apart on the same beach differed by 1 to more than 2 orders of magnitude. Concentrations of *E. coli* in swash-zone materials collected during February were in the same range as concentrations in many samples collected during the summer.

Although there are no regulatory standards for *E. coli* in swash-zone materials, the high concentrations found in this study could be of some concern for public health. Additional work is needed to better define in space and time the distributions of *E. coli* and pathogen concentrations in swash-zone materials and to determine the factors that affect these concentrations.

E. coli and Enterococci in Beach Water, Grand Traverse Bay, Lake Michigan

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In October 2000, the U. S. Congress passed the Beaches Environmental and Coastal Health (BEACH) Act, which requires states with marine or Great Lakes coastal recreational waters to adopt water quality standards using published USEPA criteria, currently based on concentrations of *Escherichia coli* (EC) and enterococci (ENT) bacteria. Little information is available that specifically compares EC and ENT in the same freshwater setting, and ENT data have rarely been collected for fresh waters.

We conducted a Pilot Study (2000) and a Trial Monitoring Program (2001) at beaches in the Grand Traverse Bay, Michigan, in collaboration with the Grand Traverse County and Benzie-Leelanau District Health Departments. *E. coli* and enterococci at 3 beaches at the southern end of the bay were similarly correlated with wind speed or direction, wave height, total suspended solids (TSS), and morning collection time and occurred at similar concentrations in bird feces (10^8 per day per bird), storm-drain water (10^7 per day) or river water (10^{11} per day). EC and ENT concentrations in shallow swash zone and knee-deep beach sands, shallow ground water, and water with detritus were up to 25 times those in beach water. Enterococci-based criteria were exceeded more frequently than *E. coli*-based criteria, offering conflicting interpretations of recreational water quality. Enterococci isolates included species that may be human pathogens and some exhibited high-level resistance to human-use antibiotics. Both studies indicated a 48-72 hr lag between rainfall and elevated *E. coli* concentrations at southern-end beaches. In contrast, *E. coli* concentrations at beaches on the West and East Bay shorelines were correlated with 24-hr antecedent rainfall. These results indicate that, in addition to local sources of contamination, beach-monitoring programs must also consider larger-scale processes associated with the characteristic 3-5 day cycle of low- and high-pressure weather systems and resulting regional hydrodynamics.

Geographic Distribution of Arsenic Possibly Metabolically Affecting Nutritional Selenium

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Selenium (Se) is recognized as an essential micronutrient that functions in cellular redox regulation, thyroid hormone regulation and antioxidant protection, especially against cancers. Arsenic (As), on the other hand, although the mechanisms are not well defined, has been demonstrated to be toxic, and might biochemically behave antagonistically toward metabolic Se.

The geochemistries of As and Se under certain physicochemical conditions (redox, pH) appear to reduce the bioavailability of one over the other. Thus, the question of dietary effect and distribution of consequent diseases if the elements metabolically behave antagonistically is raised. This presentation addresses geographic distribution of both arsenic and selenium and of various diseases.

Design of an International Soil Geochemistry Sampling Program

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Patterns of many inorganic and organic chemicals in soils across broad regions of North America are relatively unknown. With such a paucity of data, questions concerning human and environmental health, such as "How frequently do soil concentrations occur at levels considered harmful?" or "How do background concentrations in this region compare to those found at a possibly contaminated site?", are currently difficult to answer. In conjunction with the Natural Resources Conservation Service, the Geological Survey of Canada, and the Consejo de Recursos Minerales (Mexico), the US Geological Survey is planning an international survey (Smith and others, 2003) to collect new information on the soil geochemistry of North America in support of answers to these and similar questions. Design of this survey differs from those previously conducted in Great Britain and elsewhere. Possible sampling designs include a uniform grid of collection sites across the entire continent, which would be both expensive and sparse; a stratified random design allowing unequal spacing between collection sites that would reduce costs but requires information on specific indicators prior to designing the network; or a design that would sample the basic units of soil mapping, the soil series, in a representative way. Sampling design issues addressed in the March 2003 program planning workshop will be highlighted in regards to addressing questions of human and environmental health. Health agencies commenting on the design and represented at the workshop included the Agency for Toxic Substances Disease Registry (ATSDR) and the National Jewish Medical and Research Center.

Nonlinear Approaches to Understanding Human and Environmental Health

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Human population growth has triggered activities that alter Earth's environment. Consequently, assessment of such dynamic changes is central to comprehending the condition and proper management of ecosystems. Conventional data analysis methodologies using long-term datasets with multiple variables are sometimes inadequate for recognizing, modeling, and forecasting responses due to parameter interplay. Nonlinear models promote interdisciplinary applications. U.S. Geological Survey scientists (in collaboration with Tulane University, New Orleans, LA) have explored the use of spatially extensive, long-term datasets from the Lower Mississippi River Valley that measure a range of phenomena at multiple scales. These data are being shown to estimate ecosystem health as a nonlinear system of measurements with certain key elements: physical (climate, chemistry, landscape, water), ecological hierarchies (populations, individuals, tissues, DNA), and humans (density, human health, socioeconomics). A meaningful subset of measurements has been assembled that can be further employed to forecast regional environmental health. Data about water systems include spatial networks and temporal flows, and point measurements of contaminants reflect human agro-industrial activities and the capacity of ecological systems to respond. For example, fractal plotting of chemical compound occurrence reveals concentration groupings that delineate anthropogenic inputs. Nonlinear analyses – such as hierarchical data mining, scaling transformations, and feedback models – are providing insights into the linkages among the complex interactions upon which environmental and human health rely.

Novel Diagnostic Biomarkers from Aquatic Animals

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Because animals are sensitive to environmental affects, they can effectively be used as sentinels for the environment. Their biological responses, biomarkers, are quantifiable with change and diagnostic of ecosystem health. Common biomarkers between humans and fish include growth, reproductive parameters, immunological processes, liver enzymes, and cellular DNA ploidy or integrity. Studying more than one biomarker per individual and multiple species per ecosystem increases confidence in health assessments.

Gamete quality parameters, being direct measures of reproductive fitness, include viability, mitochondrial function, DNA integrity, acrosome status, motility, and morphology, and are typically employed for human fertility and cytotoxicity testing. These parameters are now used with aquatic animals (e.g., carp, green swordtail, medaka, sturgeon, oyster, abalone). In a study of reproductive condition of common carp at Lake Mead, Nevada, discriminate analyses revealed that sperm viability data added to the suite of other biomarkers allowed for exact classification of fish to site. Such data integrate well with other biomarker data, may reflect transgenerational affects, and can be interpreted in terms of long-term hazards to a community or population.

Species occupying particular trophic levels may preferentially reflect environmental circumstance. At an industrially impacted estuary in southwest Louisiana, a metric that assumes that heavier fish are in better condition than lighter fish of the same length (condition factor, Kn) employed historic data on dependent variables (season, sex, and species) from control sites. The Kn for spotted seatrout ($p=0.0009$) and red drum ($p=0.0273$), but not black drum or southern flounder, were significantly lower than those from the reference sites.

Integrity of DNA and cell proliferation on cells from aquatic species are routinely measured by flow cytometry. A genetically modified or transgenic fish model is now available to enhance the efficiency of screening for genotoxicity and of evaluating the biological relevance of contaminants, effluents, waste streams, and complex chemical mixtures.

Use of Historical Water-Quality Data To Guide the Development and Testing of Sensors in Streams and Aquifers Used for Military and Civilian Water Supplies

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Understanding the chemical and physical characteristics of source waters (untreated water from streams and aquifers) for civilian and military supplies is necessary to develop appropriate criteria and identify waters to effectively test new sensors for chemical and biological contaminants. Knowledge of source-water characteristics also helps to (a) ensure that sensors will function in accordance with performance criteria, (b) identify sensor capabilities or limitations, including the potential for false positives or negatives, and (c) increase operator confidence in sensor technologies designed to protect human life or otherwise monitor source-water environments.

The U.S. Geological Survey National Water-Quality Assessment (NAWQA) program was implemented in 1992 to collect water-quality information and address regional and national water-resources issues. A large national NAWQA database currently is available that contains ground- and surface-water data collected with consistent methods during a 10-year period (1992-2001).

Relevant data include (a) general physical and chemical measurements (such as pH, alkalinity, specific electrical conductance, temperature, and dissolved oxygen), (b) selected inorganic constituents (including major ions and trace metals), and selected synthetic organic compounds (several hundred volatile, and organophosphate or organochlorine, hydrophilic compounds).

Single-and multivariate population statistics and graphical analyses of NAWQA data are being used to characterize chemical and physical characteristics of source-water streams and ground waters in the contiguous United States. Preliminary analyses of ground-water show historical data can reveal highly probable (or improbable) water-quality characteristics and conditions, which in turn can be used to (a) help select sites, or otherwise identify representative samples, for testing sensors, and (b) develop objective performance and operating criteria for sensors during testing and deployment.

Protecting Public Health at U.S. Beaches

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In an effort to protect public health and improve beach monitoring and public notification, Congress passed the Beaches Assessment and Coastal Health (BEACH) Act in October 2000 to amend the Clean Water Act. The BEACH Act authorizes EPA to award grants to eligible coastal and Great Lakes States, Territories, and Tribes to develop and implement their beach monitoring and public notification programs. The Act also requires EPA to develop and maintain a public right-to-know database to store and display state collected beach monitoring and notification data. This presentation will discuss State progress developing their beach monitoring and public notification programs and EPA's development of a national database and interactive website.

Now in the second year of the BEACH Act Grant program, EPA published the *National Beach Guidance and Required Performance Criteria for Grants* document and over two years, awarded $12 million in BEACH Act Development Grants to 35 eligible coastal and Great Lakes States and Territories. With completion of this first step, the National Guidance document and the grants will help coastal and Great Lake grant recipients implement effective programs for monitoring and public notification of coastal recreational waters and promote consistent programs across the country.

EPA is improving it's existing Beach Watch database and website to store and display additional State collected beach monitoring and notification data. The database and website will better enable the public to view local beach monitoring and notification data and make educated decisions before going to the beach. The database and website will also be a valuable data resource for the public and States on advisory information; recreation water quality data; State/local agency program descriptions and contacts; links to time-relevant local recreation water quality data; and access to other EPA databases such as water quality standards, designated uses, and lists of impaired waters.

Arsenic Does Not Appear To Be the Risk Factor for Bladder Cancer in the Absence of both Humic Acid and High Arsenic Levels (>350 ug/l)

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BACKGROUND: Since the 1980s, the US risk analyses for arsenic in drinking water have been based on observations from the Blackfoot-Disease endemic area of SW Taiwan where the artesian wells contained humic acids and high arsenic levels (350-2,000 ug/l) and the shallow wells lacked humic acid and had low arsenic levels (0-300 ug/l). Some villages had wells from both sources. Early studies analyzed risk by well source; Later studies analyzed only by mean arsenic level for wells in each village. Both water factors have not been analyzed together.

STUDY DESIGN: We have examined the data underlying the NRC 2000 analysis in order to examine the bladder cancer risks according to water source and then to identify the additional information that was learned from examining the specific arsenic levels within the water source groups.

RESULTS: We found that the bladder cancer mortality risk was not associated with the arsenic level in villages that used either only shallow wells as their drinking water source (10-300 ug/l) or both shallow and artesian wells as their drinking water source (ug/l). We found that only for the artesian wells did the bladder cancer mortality increase with increasing level of arsenic.

CONCLUSION: We find no arsenic-related bladder cancer risk with the exception of villages solely dependent upon humic acid-containing water with high arsenic levels above 350ug/l.

Sediment Contamination Issues in Santa Monica Bay, California

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The greater Los Angeles area has a population in excess of 15 million and is the major industrial center on the west coast. Industrial and domestic wastes enter the adjacent urban ocean through sewer outfalls, coastal drainages, and direct industrial discharge. Contaminants often adhere to organic and mineral particles, which are transported in the water column and deposited on the seabed. Because the dominant current direction along the Los Angeles margin is toward the northwest, contaminants from all along the margin move toward Santa Monica Bay, the body of water lying toward the west of the most developed part of Los Angeles. Indeed, by a number of measures, Santa Monica Bay is the most contaminated part of the Los Angeles margin.

The USGS, in collaboration with local and other federal agencies, conducted a 5-year study of sediment contamination in Santa Monica Bay. The study included bottom samples, acoustic mapping, bottom photography, geophysical profiling, and physical oceanographic measurements. Sediment cores were analyzed for geologic properties, levels of contamination, age, toxicity, and biota. A synthesis of the data shows that at many locations, the sediment is highly contaminated. However, in most of these locations, the levels of contamination and toxicity are decreasing with time as a result of source control and better sewage-treatment procedures.

Chemistry and Morphology of Amphibole Asbestos from Libby, Montana: Implications for the Health, Mineralogical, and Regulatory Communities

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Asbestos is a commercial term applied to seven regulated minerals that occur in asbestiform habit. Six of these minerals are members of the amphibole group. Regulators and health experts use commercial nomenclature for amphiboles. Mineralogists classify amphiboles by a system based on crystal site chemistry that often assigns different mineral names. This dual system of nomenclature is problematic for the regulatory, health and mineralogical communities because within any single geologic occurrence or locality, amphibole compositions can vary substantially. This is certainly true for the amphiboles from the Rainy Creek Complex at Libby, Montana. Libby amphiboles include tremolite and actinolite asbestos, but also several more unusual, and unregulated varieties such as winchite and richterite asbestos. Electron probe microanalysis reveals that these phases are in complete solid solution and are intermingled at the micrometer scale. In addition to chemical variability, the Libby amphiboles exhibit a wide range of regulated and unregulated morphologies from truly asbestiform to blocky, non-fibrous grains. Asbestiform fibers, acicular particles, particles showing curvature, and cleavage fragments are all found in the Libby amphibole. These different chemistries and morphologies, intermingled at the micron scale, may each possess unique properties that could influence how they behave within the respiratory and gastro-intestinal systems and how they are regarded in regulatory assessments.

It is well known that inhalation of asbestiform mineral dust is a causative factor for diseases such as asbestosis and mesothelioma. However, the mechanisms of disease development following asbestos insult are presently unclear. Recent findings indicate that certain morphologies as well as chemical and surface properties may play a significant role in disease development. The ultimate understanding of these mechanisms will require close collaboration between toxicologists and mineralogists.

The Significance of Wildlife Disease Information Management for Human and Animal Health

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Disease has long been recognized as one of the potentially limiting factors on wildlife populations and a threat to biological diversity. Now, the rapid spread of established diseases; the emergence of new diseases in humans, domestic animals, and wildlife; and the threats of bioterrorist attacks have attracted considerable public attention, as well as generated a call for action. Additionally, intermingling of livestock and wildlife and an increasing market for domestic and international trade in animal species have created new opportunities for disease transmission.

An important factor regarding wildlife and zoonotic diseases is the use of wildlife as sentinels for public and domestic animal health threats. West Nile Virus (WNV) is a prime example of this. The virus has not only expanded geographically at an alarming rate, but has also infected a number of other species besides avian populations, including humans. Since the first documented cases in 1999, wild bird mortality has been an accurate indicator of the extent of WNV, and it continues to provide an early warning system for the emergence of the virus in new locations and other species, including human populations.

A significant problem has been the lack of an information management system for wildlife diseases because few wildlife disease databases exist on a national or international scale, and *no* central database or information system exists for common access to geospatial wildlife disease information. In response to this problem, the National Biological Information Infrastructure (NBII), an electronic information network that provides access to biological data and information, has set up the Wildlife Disease Information Node (WDIN).

The WDIN is developing a Web-based monitoring and information system with access to near real-time geospatial data on wildlife mortality events and other critical related information. This information system can be used to visualize clusters of morbidity and mortality events, identify trends, track the spread of various diseases, make predictions, lead to the identification of previously unrecognized wildlife-human-domestic animal disease interactions, limit further spread, and prevent future outbreaks. For additional information, visit: <http://wildlifedisease.nbii.gov>.

Incorporating Emerging Sensor Technologies into Existing Near-Real-Time Water-Quality Monitoring Stations

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Concern about the security of civilian and military water supplies has accelerated the development of new sensors for monitoring contaminants in water. Successful use of new sensors requires that their deployment be accomplished in a manner that provides valid information about the system being monitored. Advance field-testing is recommended as a means to assess sensor performance under real operating conditions. Near-real-time water-quality monitoring stations that collect continuous water-quality data could be convenient platforms for advance field-testing and subsequent deployment of new sensors.

Advantages of deploying new sensors at currently operating near-real-time stations include the availability of data logging and transmission equipment, shelter to protect instrumentation, a power source (electricity or battery), and for some stations, an autosampler to archive samples for analysis. An additional advantage is the potential use of near-real-time data from proven technologies to supplement and support the interpretation of data obtained from new sensors. For example, parameters that are now routinely measured (such as specific conductance or turbidity) would likely correlate with some of the parameters that would be monitored using new technologies, and the ability to identify digressions from such correlations would be useful in determining which water conditions most greatly affect sensor performance.

Technical considerations for testing new sensors include determining current background levels of the target analytes, quantifying natural variability associated with diurnal patterns, seasonality, or precipitation events, and anticipating conditions that can interfere with sensor performance. Following successful field-testing, deployment of new sensors in conjunction with current water-quality monitoring technologies at near-real-time stations would allow for timely water-quality data transmission that would enable a prompt response to critical events. With sufficient funding and support, a comprehensive network of near-real-time water-quality monitoring stations could be developed to support the needs of local and National emergency preparedness programs.

Potential Health Hazards of Owens Lake Dust

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Mineral dusts from the desiccated playa of Owens Lake, Calif., contain elevated concentrations of many metals known to have toxic effects. To assess the element sources and possible hazards to humans, other animals, and plants, we are (1) analyzing trace-element contents of the fine-grained mineral and soluble fractions of deposited dust, playa sediment, and aerosol samples collected during dust storms, and (2) repeating these analyses by extracting the same samples using solutions that are surrogates for human lung and gastric fluids.

Dusts and aerosols are strongly enriched in sulfate from soluble sodium sulfate in playa sediment: elemental S concentrations in saline dust events can be as much as 10 % by weight. Potentially toxic elements in the <50 μm fraction of deposited dust include (conc. in ppm): As (10-50), Cr (17-56), Cu (≤22), Mo (0.5-3), Ni (≤16), Pb (50-400), Sb (6-14), Th (10-16), and U (3-8). Leach tests of the dusts using water and simulated lung fluids (20:1 fluid:dust by wt., 24 hr mixing) show these metals are quite soluble and bioavailable (i.e., dissolved As, Mo, and U as much as 2700, 650, and 170 μg/L, respectively).

Dust-deposition rates of some metals and sulfates in Owens Valley equal or exceed rates in industrialized areas of the world. Much Owens Lake dust is <10 μm in diameter, and SEM studies reveal abundant submicron particles. Given composition, size, and deposition rates (1991-1998 average of 150 $g/m^2/yr$ of fine dust at one site), a large fraction of these metals could be transported hundreds of kilometers and easily respired. Terminal lake basins such as Owens Valley could be globally important sources of metal-bearing dusts. The health and ecological effects of soluble alkaline sulfate aerosols are poorly known but of potential concern.

The Environmental Geochemical Causal Factor in Environmental Medicine: Synergetic Determination of Baseline Data for Newly Developing Regions

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The geochemical environment is a vital element of the environmental causal factor initiating adverse health affects. Newly developing regions of the world like the East Asian region embracing industrialization and undergoing rapid urbanization are targets for geochemical pollution. After a review of the geochemical environment and health and the conducive conditions for geochemical activity of an environment existing in this region the geochemical information necessary for health assessment is considered with respect to its availability mentioned in published sources for such an environment. The data requirements for characterizing the geochemical environment and the approach towards resolving the deficiency in this pressing requirement to enable an assessment of its impact on public health is then put forward.

Geochemical Baselines and Human Health

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Concerns continue to increase about potentially harmful chemical substances in the environment and their effects on human and animal health, crops, and the sustainability of the Earth's life support systems. The substances of concern include metals such as lead, cadmium, chromium, nickel, zinc, copper, uranium, molybdenum, mercury, arsenic, and antimony. Throughout the developed world, these metals are subject to increasingly stringent regulation aimed at progressive reduction in chronic exposure. Unfortunately, the knowledge of the abundance and spatial distribution of these elements in soils of the United States is severely limited. The most-often-quoted data set for background concentrations of metals and other trace elements in soil of the conterminous United States consists of only 1,323 samples (about 1 sample per 6,000 km^2) collected during the 1960s and 1970s by the U.S. Geological Survey (USGS) (Boerngen and Shacklette, 1981; Shacklette and Boerngen, 1984). The samples were collected from a depth of approximately 20 cm from non-cultivated fields having native vegetation.

The USGS and the Natural Resources Conservation Service are currently studying the feasibility of a national-scale soil geochemical survey that will increase the sample density by at least an order of magnitude. As currently envisioned, the survey would perform the normal chemical analyses for total element content and also conduct selective extractions to establish a bioavailability database at a national scale. Selected organic compounds, including pesticide residues, would be analyzed on a subset of the samples and microbial characterization would be determined on a limited number of samples.

Geochemical Maps Based on Ultra-Low-Density Sampling of the Conterminous United States

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The U.S. Geological Survey, under the leadership of H.T. Shacklette, collected soil and other regolith samples from 1,323 sites in the conterminous United States (7,840,000 km^2) from 1961-1975 and prepared single-element, point-symbol geochemical maps in black and white for 7 major and 39 trace elements. We have reprocessed these data, using weighted median and Bootstrap procedures for interpolation and smoothing, and produced full-color maps for 7 major elements (Al, Ca, Fe, K, Mg, Na, and Ti) and 15 trace elements (As, Ba, Cr, Cu, Hg, Li, Mn, Ni, Pb, Se, Sr, V, Y, Zn, and Zr). Comparison of the K map produced in this manner with a corresponding map produced from airborne radiometric measurement of K shows that the reliability of these maps is good even with the ultra-low sample density. The low-density maps successfully reveal broad geochemical dispersion patterns for both major and trace elements. The observed patterns are related to general soil-forming processes such as climate and parent material and to human influence on the environment. The Shacklette data set and the geochemical maps produced from the data set are used on a regular basis by regulatory agencies of the Federal and state governments to set "action" levels and "remediation" levels of harmful trace elements in soil. The data and maps may also prove useful in estimating chronic exposure levels resulting from potentially harmful elements in soil. The USGS and the Natural Resources Conservation Service are currently studying the feasibility of a national-scale soil geochemical survey that will increase the sample density by at least an order of magnitude.

Mapping Natural Occurrences of Potentially Asbestos-Bearing Serpentine Rocks in the Foothills of the Sierra Nevada, California Using Imaging Spectroscopy

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The health effects of asbestos dust are a growing concern in the foothills of the Sierra Nevada in California, with the population expected to increase by 40,000 in El Dorado County over the next decade. Rapid population growth drives infrastructure development that potentially brings people into contact with rock-derived asbestos dust on roads, construction sites, homes, and even school playgrounds. El Dorado County, like many of the surrounding counties in the foothills and coast ranges, is underlain by metamorphic rocks with numerous outcrops of chrysotile-bearing serpentines and tremolite-rich rocks.

Current laboratory methods of screening for asbestos are expensive and time consuming. This study reviews a new method for assessing asbestos potential where surface mineralogic information about asbestos occurrences is derived from remote sensing imagery and compared to results of field sampling and information from existing geologic maps. Our goal is to develop a relatively quick low-cost asbestos screening tool that can be used in the field and with airborne sensors. In August, 2001, the AVIRIS imaging spectrometer was flown over 12 study sites in El Dorado County with the intent of spectrally mapping the extent of serpentinization and identifying outcrops of chrysotile and tremolite asbestos. At locations where the identification of surface materials is limited by thick vegetation, we are exploring the possibility of using the spectral signature of the vegetation as an indicator of underlying serpentine-bearing rock.

Water-Quality Monitoring of Chemicals Used To Combat West Nile Virus

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West Nile Virus, a mosquito-borne disease, was first detected in the United States in 1999 in New York City. Since then, air and ground spraying of insecticides and insecticide briquettes have been used throughout neighborhoods in the New York metropolitan area to reduce mosquito populations and thus the risk of human illness. A study was initiated to develop and test analytical methods to detect toxicologically relevant amounts of these insecticides.

Ground-water and surface-water samples from the New York metropolitan area were analyzed for methoprene (an insect growth regulator), malathion (an organophosphate), two pyrethroid compounds (phenothrin and resmethrin), and piperonyl butoxide (a chemical synergist used with pyrethroids) using a newly developed gas chromatography / mass spectrometry (GC/MS) method. Methoprene acid, a methoprene degradate, was analyzed using immunoassay. More recently, passive in-situ samplers, semipermeable membrane devices (SPMDs), were used to measure the bioavailability of these chemicals to fresh- and saltwater fish. All analyses have method reporting limits in the part-per-trillion range.

Piperonyl butoxide was detected after applications of pyrethroids had been made, but rarely were the pyrethroids detected. Methoprene and its degradate, methoprene acid, were rarely detected despite relatively widespread use. Malathion was not detected. The analytical methods used is this study are valuable for acquiring knowledge about the fate and transport of these mosquito insecticides and synergist in water.

Development of a Prototype Real-Time Early-Warning Monitoring Network for Drinking-Water-Supply Safety and Security

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A consortium of scientists and water-supply engineers from the U.S. Geological Survey (USGS), U.S. Environmental Protection Agency (USEPA), Rutgers University, New Jersey Department of Environmental Protection, and three water suppliers in New Jersey is developing a prototype real-time early-warning monitoring network for drinking-water safety and security. The objectives for the prototype system are (1) to develop and assess a methodology, (2) to test and compare new sensors, and (3) to provide water-supply managers and operators with real-time information to protect the integrity of the water supplies from accidental or intentional contamination. The prototype network will build on the USGS real-time network of streamflow-gaging and water-quality-monitoring stations by upgrading equipment or adding stations at locations upstream from surface-water intakes in the source water, near the intakes, and in water-distribution systems. Traditional sensors that measure temperature, pH, dissolved oxygen, specific conductance, and turbidity will be used in conjunction with new biological, chemical, and radioactive sensors as they become available. The new sensors will be bench tested at the USEPA Test and Evaluation Facility in Cincinnati, Ohio, or by the USEPA Environmental Testing and Verification Program. Those promising sensors then will be deployed and tested in the field. Real-time data streams will be transmitted by satellite to appropriate facilities. Computer models will be developed to interpret the real-time water-quality data so that appropriate management decisions can be made that are relevant to the safety and security of drinking water.

Geologic Environments that Form Vermiculite and Amphibole Asbestos

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Vermiculite was mined and milled near the small town of Libby in northwestern Montana from 1923 to 1990. High rates of mortality due to asbestosis in Libby mine, mill workers and residents have been linked to amphibole asbestos particles intergrown within the Libby vermiculite ore and gangue rocks. The USGS has conducted a reconnaissance study to determine if amphibole asbestos minerals are common in other vermiculite deposits.

This study of U.S. vermiculite was made possible via an archived collection of vermiculite-rich samples collected from 62 vermiculite mines and deposits in 10 U.S. States; these samples were collected during the 1940s, '60s, and '70s as part of a reconnaissance survey of the Nation's vermiculite resources. The samples were compared to a representative suite of 30 samples collected from the former mining operations at Libby. In the current study, splits of each sample were analyzed by X-ray diffraction, scanning electron microscopy, energy-dispersive spectroscopy, and electron probe microscopy.

Despite the reconnaissance nature of the sampling, the mineralogic characterization of the vermiculite samples yielded consistent results. Our analyses indicate that asbestiform amphiboles (fibers) are not common in all types of vermiculite deposits, but also showed that the Libby deposit is not unique in its mineralogy. Vermiculite deposits that formed in geologic settings similar to the Libby deposit—relatively quartz deficient, K-Na-Ca-rich igneous intrusions, typically zoned—can contain fibrous amphiboles with compositions similar to those at Libby. In addition, vermiculite deposits that formed where masses of ultramafic rock were intruded by granite and (or) pegmatite can contain fibrous amphibole. The relationship between geologic setting and asbestos content can be used to prioritize reclamation and monitoring of active and abandoned vermiculite mines, at a time when vermiculite deposits are under scrutiny as potential sources of environmental asbestos.